ARS 74—57
March 1971

HIGH AND LOW PROTEIN FRACTIONS BY SEPARATION MILLING OF ALFALFA

Agricultural Research Service
U. S. DEPARTMENT OF AGRICULTURE

PREFACE

The work reported in this publication was done under a Memorandum of Understanding, first with the Nebraska Department of Agriculture and Inspection, and later, with the Nebraska State Department of Economic Development. Considerable financial support was furnished throughout the term of the project, by the Nebraska State Departments. In 1968, the Nebraska Alfalfa Dehydrators Association also contributed financially.

This report was prepared at the Western Regional Research Laboratory, Albany, Calif. 94710--headquarters of the Western Marketing and Nutrition Research Division, ARS, USDA. Copies are available upon request.

ACKNOWLEDGMENTS

We are greatly indebted to the owners, management, and many of the employees of Nebraska Farm Products, Inc., Cozad, Nebr.; Shofstall, Inc., Odessa, Nebr.; Platte Valley Products, Inc., Lexington and Darr, Nebr. and Dixon Dryer Company, Dixon, Calif. for their help and cooperation in carrying out the field studies. Our thanks go also to the California Pellet Mill Company, San Francisco, Calif., for the generous loan of equipment for several years. Kenneth V. Smith of the Western Regional Research Laboratory aided very materially in nearly all phases of the operations. D. White, A. L. Livingston, and Richard Knowles of Field Crops Laboratory performed the analyses. The Analytical Investigations in the Chemical Physics Laboratory made thousands of determinations.

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HIGH AND LOW PROTEIN FRACTIONS BY SEPARATION MILLING OF ALFALFA

BY JOSEPH CHRISMAN[1], GEORGE O. KOHLER[2], A.C. MOTTOLA[2], AND J.W. NELSON[3]

NEED FOR THIS STUDY

Dehydrated alfalfa, "dehy," is used in the rations of almost all animals of commercial significance in the market place and of those grown for pets and those for laboratory use.

The commercial grades of alfalfa, on a guaranteed basis, as given in the Official Publication of the Association of American Feed Control Officials (1968) are:

13 percent crude protein, crude fiber not more than 33 percent.

15 percent crude protein, crude fiber not more than 30 percent.

17 percent crude protein, crude fiber not more than 27 percent.

18 percent crude protein, crude fiber not more than 25 percent.

20 percent crude protein, crude fiber not more than 22 percent.

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These grade designations would seem to indicate that the protein and crude fiber content of an alfalfa product constitute a good guide to the overall quality of the material in using it as a feed ingredient. This is generally true. However, a good negative correlation exists between protein and fiber in dehydrated alfalfa. As protein increases, fiber diminishes and practically all of the vitamins of alfalfa increase. The xanthophyll, which is not a nutritional essential but of great importance when the alfalfa is fed to broilers or layers, also increases as protein increases.

Since those relationships do exist, we use the protein and fiber values throughout this report as indicators of the quality of the material we are working with or fractions we make.

However, protein and fiber content do not tell the whole story of the needs of the feed formulator or of the various classes of livestock that consume such fractions.

There are two general classes of these animals that eat dehydrated alfalfa--(1) monogastric or simple (one) stomached and (2) ruminants or multiple-stomached. The nutritive needs of these two classes of animals differ very materially. Likewise, their ability to make good use of protein, fiber, the vitamins, and xanthophyll differ.

Ruminants, such as cows, sheep, and goats, can utilize fiber to their benefit; monogastric animals, such as poultry and swine, cannot. Ruminants manufacture their own water soluble vitamins; monogastric animals must have them from an outside source. There is no need for xanthophyll in the ruminant ration. However, in many markets, the need for xanthophyll is mandatory in poultry rations, because of the demand for yellow skin and fat in broilers and for dark yellow egg yolks.

In fractionating dehydrated alfalfa, the purpose is to make products better suited to each of the two classes of animals than is the whole alfalfa. A product high in protein, vitamins, and xanthophyll with the least possible fiber is needed for feeding poultry and swine, and a complementary fraction, lower in protein and higher in fiber for the ruminants.

Over 500 drums are used in dehydrating alfalfa. In the United States, about 1,700,000 tons of dehydrated

alfalfa is manufactured annually (15).[4] With no means of fractionation, the quality of the output is governed by the quality of the growing crop at the time alfalfa is harvested. The range of quality, as judged by its protein content, varies from a low of about 13 percent to a high of about double that, or 26 percent. At least 75 percent of this alfalfa comes from areas where crop quality is subject to the vagaries of weather. The other 25 percent is produced in areas where rainfall or drought do not materially affect the growing crop and irrigation is mandatory. In areas where weather is unstable, the average quality of all alfalfa for the year will be between 17 and 18 percent protein, with the range being from a low of perhaps 12 percent to a high of about 25 percent. In the irrigated areas the average will be closer to 20 percent with a range of about 15 to 28 percent.

The most widely used dehydrated alfalfa consists of 17 percent protein with not more than 27 percent fiber and a guarantee of at least 60 milligrams per pound of carotene. A product containing 20 percent protein with 22 percent fiber and 90 mg./lb. carotene will bring a premium in the market over the price of 17 and 22 percent protein, 19 percent fiber with a higher carotene guarantee will bring a premium over the 20 percent product.

Custom, in the dehydrator-feed manufacturer relationship, has established the protein-fiber-carotene guarantees. We feel that a substitution of xanthophyll guarantee for the carotene guarantee would be more meaningful now that synthetic vitamin A is in wide use in all feeds while xanthophyll is found in meaningful concentration in very few products, among which dehydrated alfalfa is the most widely used.

Two avenues are open for the dehydrator to furnish any one of the established grades for the year-round market: First, by selection, during the operating season, of those lots produced that meet the specifications--15, 17, 20, or 22 percent protein. Second, by blending, storing the various qualities separately under inert gas, and pulling from two or more tanks to make a blend of 17 or 20 percent. Grades higher than 20 percent usually must be acquired largely by the selection method, which is limited

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[4] Underscored numbers in parentheses refer to Literature Cited, p. 50.

by weather and crop conditions. For instance, if rains are heavy and frequent in the Platte Valley of Nebraska throughout May and June, there is not much chance of dehydrated alfalfa grading 20 percent or better because of delayed harvesting of the first and second cuttings. Month-long dry spells following the heavy rainfall period can further disrupt the harvesting cycle.

The data presented in this publication show that by a simple fractionation process the dehydrator can remove many of the uncertainties of his being able to supply the market in an orderly manner, to provide greater quantities of the higher grades regardless of the weather hazards, and be in a much better position to meet his commitments in the market at all times. Our study has had two objectives--(1) more suitable alfalfa products for animal feeding and (2) better assurance that the dehydrator can always supply his markets.

By fractionation the dehydrator may also safely offer the feed formulator a grade above any of those listed. A 25-percent protein product containing not more than 17-percent fiber is easily possible. Such a product contains 40 to 50 percent more protein and 30 to 40 percent less fiber than the 17-percent protein commercial grade. At the same time the carotene and xanthophyll will be increased by about 40 to 50 percent (3,4).[5]

As desired for cattle feeding, the complementary fraction, higher in fiber, can be pelleted or wafered in

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[5] Kohler, G. O., and Chrisman, J. Separation milling of alfalfa. Proceedings of the 20th Alfalfa Improvement Conference, University Park, Pa., July 6-8, 1966 (CR 58-66) p. 46.

Kohler, G. O., and Chrisman, J. Separation milling of alfalfa. Western Division American Society of Agriculture Engineers Annual Meeting in San Mateo, Calif. 1968.

Kohler, G. O., and Chrisman, J. Results of chemical analysis. Nebraska Alfalfa Dehydrators Association Meeting, Lincoln, Nebr. 1969.

Kohler, G. O., Chrisman, J., Bickoff, E. M., and Spencer, R. R. Separation milling and grass-juice-Southern California style. American Dehydrators Association Convention Proceedings. 1969.

large sizes to retain parts of the stem that are 1/2 to 3/4 inch long. The pelleted alfalfa will still contain 10- to 15-percent protein. Thus, each of these new products is better suited to the animals to which it will be fed.

In the past 10 years, several well-qualified people have told of the need to furnish improved alfalfa products, for the feed industry, particularly for monogastric animals, such as poultry and swine.

R. M. Bethke speaking before the 1959 American Dehydrators Association convention raised the question--"Could the dehydrated alfalfa industry follow a similar practice [soybean process] and supply the feed industry with a lower fiber and higher carotene, vitamin E, and xanthophyll product that is economical to use?"

R. O. Nesheim, addressing the 1960 convention of the same Association, in discussing swine feeding said: "I believe that you can increase your foothold in this area by further upgrading your product. A product higher in carotene, lower in fiber, higher in its content of riboflavin and other B vitamins will be more attractive to use in these formulas providing it is competitive in cost."

Francis H. Bird, engaged in poultry nutrition research for Eastern States Farmers Exchange, speaking before the 1960 ADA Convention, made the following statement: "Studies should be undertaken on methods for upgrading alfalfa meal giving more of the essential factors in a concentrated form."

D. F. Middendorf at the 1966 convention of the dehydrators told them, "All poultry nutritionists would be very interested in alfalfa products that would have less fiber and more nutrients per pound--more effective nutrients."

At this same convention T. J. Cunha stated, "Dehy in a sense is preserved pasture in a concentrated form. The possibility of producing a higher protein, lower fiber alfalfa meal offers an excellent possibility to increase the use of dehy in the ration of swine in the future."

Other methods of producing fractions of alfalfa better suited to their end uses in feeding livestock have been and are being tried.

At Iowa State University a leaf harvesting machine has been developed. The leaves are stripped from the

growing stalk in the field and dried separately. The stalks are left in the field for regeneration of new leaves or they are harvested as a second crop from the same field as a lower grade of stemmy alfalfa (1).

Workers at Michigan State University have reported research on drying of leaves stripped from alfalfa plants in the field.[6/]

The Research Institute for Feeding Stuffs of the Czechoslovakian Academy of Agricultural Sciences (8) described a method called "storyed" harvesting. This is a double harvesting of the alfalfa. First the upper parts of the plant are cut and then the lower. Then the upper part is dehydrated and the lower sun cured.

Workers at Nebraska University have also experimented for several years with "storyed" harvesting in efforts to obtain two grades of dehydrated alfalfa (11).[7/]

ALFALFA PLANT COMPOSITION

Preliminary to our semi-commercial and commercial applications of fractionation laboratory and pilot plant experimentations were conducted to learn more about the alfalfa plant and the distribution of protein, fiber, and sometimes ash in its various physical parts. Other researchers have done much work of this nature in the past (7,12,13,17,18,19). In one experiment, we separated by hand into six fractions 10- to 14-inch stalks of pre-bud Lahontan alfalfa which were cut in mid-June. The following were the results:

	Weight Percent	Protein Percent	Fiber Percent
Leaf midribs	5.4	30.3	11.1
Petioles	5.2	21.2	17.6
Terminal buds	5.4	38.1	13.2
Epidermis	8.9	17.3	24.2
Leaf less midribs	40.6	37.3	7.0
Stem less skin	34.5	13.2	40.7
Total	100.0	---	---
Average	---	26.0	21.3

6/ Whitney, L. F. and Hall, C. W. Harvesting and drying of alfalfa leaves 1963. Winter meeting of the American Society of Agricultural Engineers.

7/ Kehr, W. R., and Ogden, R. L. Management for forage quality. Proceedings of the American Dehydrators Association 23d Annual Convention. 1965.

In this experiment, 72 percent of the protein lies in 51 percent of the alfalfa comprising leaf midribs, leaf, and buds. This same fraction contains only 19.5 percent of the fiber. In a later experiment the number of fractions was reduced to four--leaf, bud, petiole, and stem.

Throughout this report all analyses are given on a 93-percent total solids basis as being more meaningful to commercial producers of alfalfa products.

LABORATORY STUDIES

Alfalfa samples of the California common variety were taken from a plot belonging to the University of California. The plot is known as the Gill Tract which is adjacent to the Western Regional Research Laboratory.

Cutting was started on July 23, 1962, when the stand was about 10 inches tall. Successive cuttings were made each Monday for seven total cuttings. By September 4 the plot was badly infested with insects, leaf spot was widely prevalent, and leaf drop and yellowing were taking place. We concluded that further sampling under these conditions would not yield significant data for comparison with earlier cuttings.

At the time of the 4th, 5th and 7th cuttings, we used another method of fractionation in addition to the dissecting method. A number of stalks of standing plants, taken at random, were stripped by hand. Using rubber gloves, we grasped the stem at the base between two fingers with sufficient tightening to strip the stem of practically all of its leaves. In doing so, practically all branchlets were removed and the stem itself would break near the top of the plant. The stem was then cut about 2 to 3 inches above the ground and the two resulting products dried and ground for analysis. The stripping method is similar to the Iowa work mentioned earlier (1).

By combining the analytical results covering leaves, buds, and petioles obtained by hand separation, we were able to compare this dissecting method with stripping. The composition by weight, protein, and fiber composition was very close for the two methods as shown in table 1.

The data covering the seven samplings which were hand-dissected in the laboratory are shown in tables 2 and 3.

TABLE 1.--Distribution of components by stripping and dissecting

Item	Cuttings of 8/13/62		Cuttings of 8/20/62		Cuttings of 9/4/62	
	Stripping	Dissecting	Stripping	Dissecting	Stripping	Dissecting
			PERCENT BY WEIGHT			
Leaf	60.43	56.08	55.69	54.74	52.81	55.42
Stem	39.57	43.92	44.31	45.26	47.19	44.58
Total	100.00	100.00	100.00	100.00	100.00	100.00
			PERCENT PROTEIN			
Leaf	25.6	26.4	23.4	25.9	23.7	24.9
Stem	9.2	9.8	9.2	8.9	8.7	9.4
Average	19.1	19.1	17.1	18.2	16.6	18.0
			PERCENT FIBER			
Leaf	11.3	11.4	10.5	12.5	13.4	11.5
Stem	40.0	39.8	39.0	40.0	43.0	39.6
Average	22.7	23.9	23.4	24.9	27.3	24.0
			PERCENT ASH			
Leaf	8.7	9.4	11.6	10.0	9.9	11.7
Stem	3.7	4.0	4.5	4.0	3.7	4.1
Average	6.7	7.0	8.5	7.3	7.0	8.3

TABLE 2.--Analytical data on hand-dissected California common alfalfa samples from Albany, Calif., 1962

Item	1st week 7/23	2d week 7/30	3d week 8/6	4th week 8/13	5th week 8/20	6th week 8/27	7th week 9/4	Average 7 weeks
Leaf:								
Percent weight	48.09	44.12	45.61	46.12	44.78	46.20	41.98	45.27
Percent protein	37.1	32.7	31.8	27.9	27.3	26.6	26.2	29.9
Percent fiber	10.2	9.3	10.6	9.9	11.1	10.0	9.5	10.1
Percent ash	--	--	11.9	9.8	10.5	10.2	12.8	11.1
Buds:								
Percent weight	6.77	6.14	2.63	3.25	3.30	5.07	6.60	4.82
Percent protein	31.6	25.4	30.0	26.6	27.3	26.4	25.8	27.6
Percent fiber	18.1	18.9	18.1	18.5	18.2	18.2	16.2	18.0
Percent ash	--	--	8.3	6.4	6.5	6.1	6.7	6.8
Petioles:								
Percent weight	4.57	3.79	7.35	6.72	6.65	6.60	6.84	6.07
Percent protein	18.3	18.4	19.3	16.0	16.0	15.4	16.2	17.1
Percent fiber	18.4	19.1	19.3	18.6	19.3	19.8	19.0	19.1
Percent ash	--	--	9.3	8.2	8.5	8.3	9.6	8.8
Stem:								
Percent weight	40.56	45.96	44.51	43.91	45.27	42.13	44.58	43.83
Percent protein	17.1	12.8	11.9	9.8	8.9	8.8	9.4	11.2
Percent fiber	28.6	36.2	40.1	39.8	40.0	40.5	39.6	37.8
Percent ash	--	--	4.9	4.0	4.0	4.2	4.1	4.2

TABLE 3.--Distribution of components on hand-dissected California common alfalfa samples from Albany, Calif., 1962

Item	1st week 7/23	2d week 7/30	3d week 8/6	4th week 8/13	5th week 8/20	6th week 8/27	7th week 9/4	Average 9 weeks
Percent of total protein in:								
Leaf	64.28	63.97	65.99	67.40	67.09	66.88	61.08	65.24
Bud	7.68	6.90	3.60	4.52	4.95	7.29	9.46	6.34
Petioles	3.01	3.10	6.45	5.62	5.84	5.54	6.15	5.10
Stem	25.03	26.03	23.96	22.46	22.12	20.29	23.31	23.32
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Percent of total fiber in:								
Leaf	26.44	18.13	19.72	19.04	19.87	18.85	16.59	19.81
Bud	6.59	5.12	1.95	2.52	2.41	3.75	4.45	3.83
Petioles	4.53	3.20	5.76	5.23	5.16	5.32	5.40	4.94
Stem	62.44	73.55	72.57	73.21	72.56	72.08	73.56	71.42
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Percent of total ash in:								
Leaf	--	--	63.87	64.45	64.44	64.41	64.72	64.38
Bud	--	--	2.57	2.96	2.95	4.23	5.30	3.60
Petioles	--	--	8.01	7.82	7.77	7.44	7.87	7.78
Stem	--	--	25.55	24.77	24.84	23.92	22.11	24.24
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The ash content was determined on the fractions for the final 5 weeks. Highest ash content is in the leaf fraction and almost two thirds of the total ash of the plant lies in the leaf.

A similar examination of Buffalo alfalfa was made from Douglas County, Kans. R. S. Farmer of National Alfalfa Dehydrating and Milling Co. cooperated with us by cutting alfalfa samples from a field weekly for 8 weeks in August, September, and October 1962. The samples were dried whole in an oven and placed in plastic bags for shipment so that no part would be lost. Tables 4 and 5 show the results of these examinations.

In 1963 we obtained samples of alfalfa from Nebraska, Kansas, and California of the varieties Ranger, Buffalo, Lahontan, and Moapa. We did our own sampling of Lahontan and Moapa in the fields. The samples from Nebraska (Ranger) and Kansas (Buffalo) were prepared in a manner similar to that used with Kansas samples in 1962. The leaf-stem ratios of the four varieties from the 1963 crop are as follows (ratios shown graphically in fig. 1):

Variety and date of cutting	Number of days from previous cutting	Leaf-stem ratio
Buffalo:		
4-25	--	0.950
6-3	41	.888
7-3	30	.823
8-1	27	.850
9-8	38	1.006
Ranger:		
5-15	--	.914
6-28	44	.519
8-6	38	.556
9-19	44	.668
10-24	45	1.087
Lahontan:		
4-29	--	.516
5-27	28	.631
6-24	28	.661
7-17	23	.746
8-14	28	.956
9-9	26	.962
10-21	42	.888
Moapa:		
5-17	--	0.582
6-12	26	--
7-8	26	.818
8-2	25	.875
8-30	28	.767
10-4	35	.833

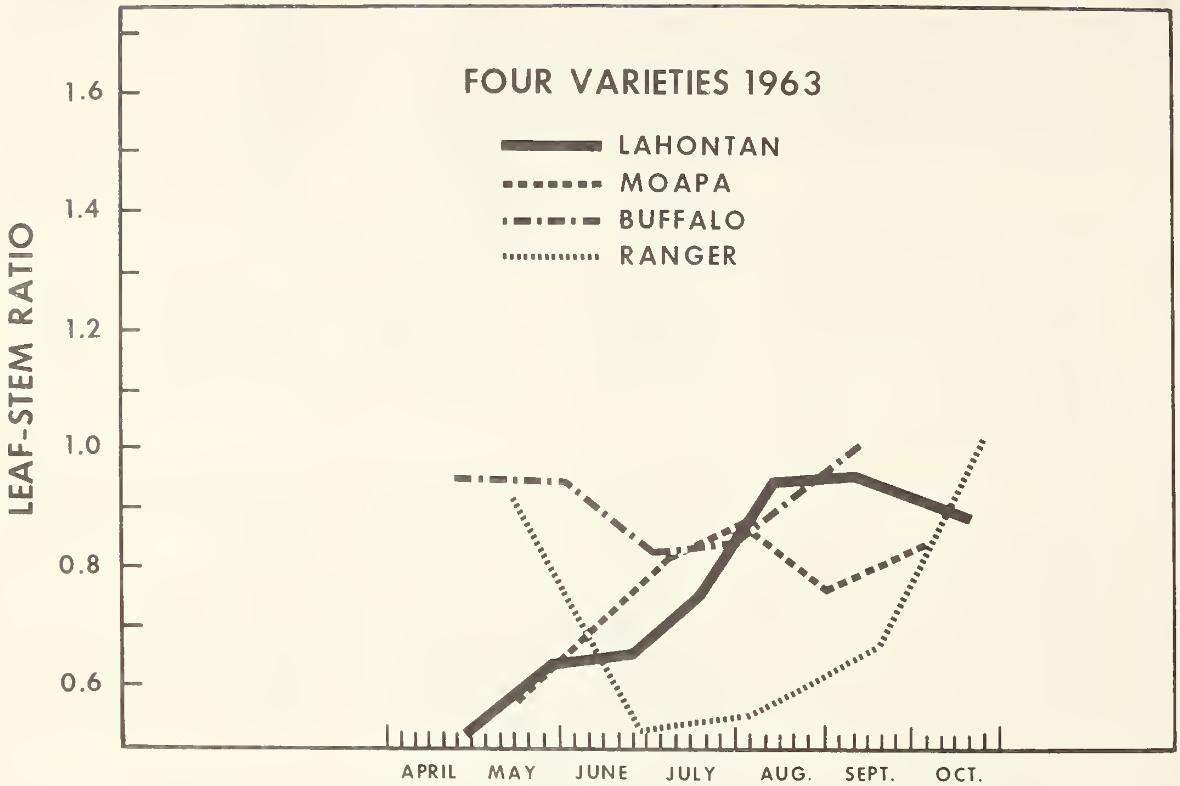

Figure 1.--Leaf-stem ratios of four varieties of alfalfa throughout producing season of 1963.

Lahontan alfalfa was sampled throughout the growing season in the Sacramento Valley in 1964 under three cuttings at 26-, 30-, and 34-day intervals. Leaf-stem ratios (fig. 2) of Lahontan alfalfa, 1964 crop, are as follows (shown graphically in fig. 2):

26-day interval		30-day interval		34-day interval	
Cutting date	Leaf-stem ratio	Cutting date	Leaf-stem ratio	Cutting date	Leaf-stem ratio
4-16	1.013	4-20	1.354	4-24	1.167
5-12	.893	5-20	.737	5-28	.625
6-8	1.205	6-19	.824	7-1	.730
7-2	1.182	7-20	.935	8-4	.847
7-28	1.156	8-19	1.200	9-8	1.127
8-24	.742	9-17	.961	10-12	1.574
9-28	1.190	10-20	1.667	---	---

Size and Composition of Commercial Dehydrated Alfalfa Meals

Because of the possibility of a suitable fractionation of dehy at a later stage in the processing of alfalfa,

TABLE 4.--Analytical data on hand-dissected Buffalo alfalfa samples from Midland, Kans., 1962

Item	1st week 8/29	2d week 9/5	3d week 9/12	4th week 9/19	5th week 9/26	6th week 10/3	7th week 10/10	8th week 10/17	Average 8 weeks
Leaf:									
Percent weight	50.25	45.36	45.17	43.24	42.63	37.65	34.83	34.62	41.72
Percent protein	38.1	36.9	30.3	28.9	27.1	28.1	26.3	26.3	30.2
Percent fiber	7.7	8.2	7.6	8.1	8.8	10.2	10.5	10.2	8.9
Percent ash	10.1	10.6	9.8	8.8	8.2	9.5	11.2	10.1	9.8
Buds:									
Percent weight	3.13	2.86	1.00	1.07	1.16	1.28	1.16	1.00	1.58
Percent protein	42.6	39.7	34.1	32.8	28.8	24.8	24.4	27.0	31.8
Percent fiber	9.5	9.7	11.3	14.0	17.0	18.1	17.7	17.0	14.3
Percent ash	9.0	8.2	7.5	7.3	6.8	7.9	9.3	7.8	8.0
Petioles:									
Percent weight	10.84	9.21	7.12	7.18	7.05	5.83	5.29	5.99	7.31
Percent protein	25.9	21.1	20.1	19.1	18.3	18.8	19.4	19.0	20.2
Percent fiber	17.3	17.9	17.0	17.4	18.5	18.1	19.5	18.0	18.0
Percent ash	13.6	13.1	10.6	12.9	10.4	10.6	11.6	10.6	11.7
Stem:									
Percent weight	35.78	42.57	46.71	48.51	49.16	55.24	58.72	58.39	49.39
Percent protein	21.6	17.3	13.1	10.5	10.4	11.4	10.6	10.5	13.2
Percent fiber	24.4	32.5	34.1	39.9	37.9	37.1	40.6	40.2	35.8
Percent ash	13.2	11.4	8.5	7.0	7.1	6.9	7.4	7.2	8.6
Whole plant (computed):									
Percent protein	31.0	27.2	21.6	19.3	18.3	18.3	16.7	16.7	21.1
Percent fiber	14.8	19.4	20.7	24.3	23.9	25.6	28.9	28.3	23.2
Percent ash	11.6	11.1	9.2	8.2	7.8	8.1	9.0	8.4	9.2
Leaf/stem ratio	1.145	0.931	0.858	0.796	0.779	0.637	0.562	0.553	0.764

TABLE 5.--Distribution of components on hand-dissected Buffalo alfalfa samples from Midland, Kans., 1962

Item	1st week 8/29	2d week 9/5	3d week 9/12	4th week 9/19	5th week 9/26	6th week 10/3	7th week 10/10	8th week 10/17	Average 8 weeks
Protein, percent of total in:									
Leaf	61.71	61.53	63.37	64.76	63.25	57.88	54.77	54.70	60.24
Bud	4.30	4.17	1.58	1.83	1.83	1.74	1.69	1.63	2.35
Petiole	9.07	7.16	6.61	7.09	7.05	6.00	6.15	6.81	6.99
Stem	24.92	27.14	28.44	26.32	27.87	34.38	37.39	36.86	30.41
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Fiber, percent of total in:									
Leaf	26.20	19.03	16.55	14.44	15.70	15.02	12.73	12.54	16.52
Bud	2.00	1.42	.54	.62	.83	.91	.71 [1/]	.61	.96
Petiole	12.70	8.47	5.86	5.14	5.47	4.13	3.59	3.82	6.15
Stem	59.10	71.08	77.05	79.80	78.00	79.94	82.97	83.03	76.37
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ash, percent of total in:									
Leaf	44.03	43.25	47.97	46.12	44.69	44.10	43.27	41.68	44.39
Bud	2.45	2.10	.82	.96	1.01	1.25	1.20	.93	1.34
Petiole	12.70	10.85	8.21	11.29	9.44	7.64	6.84	7.54	9.31
Stem	40.82	43.80	43.00	41.63	44.86	47.01	48.69	49.85	44.96
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Weight, percent of total in:									
Leaf	50.25	45.36	45.17	43.24	42.63	37.65	34.83	34.62	41.72
Bud	3.13	2.86	1.00	1.07	1.16	1.28	1.16	1.00	1.58
Petiole	10.84	9.21	7.12	7.18	7.05	5.83	5.29	5.99	7.31
Stem	35.78	42.57	46.71	48.51	49.16	55.24	58.72	58.39	49.39
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1/] Based on estimate.

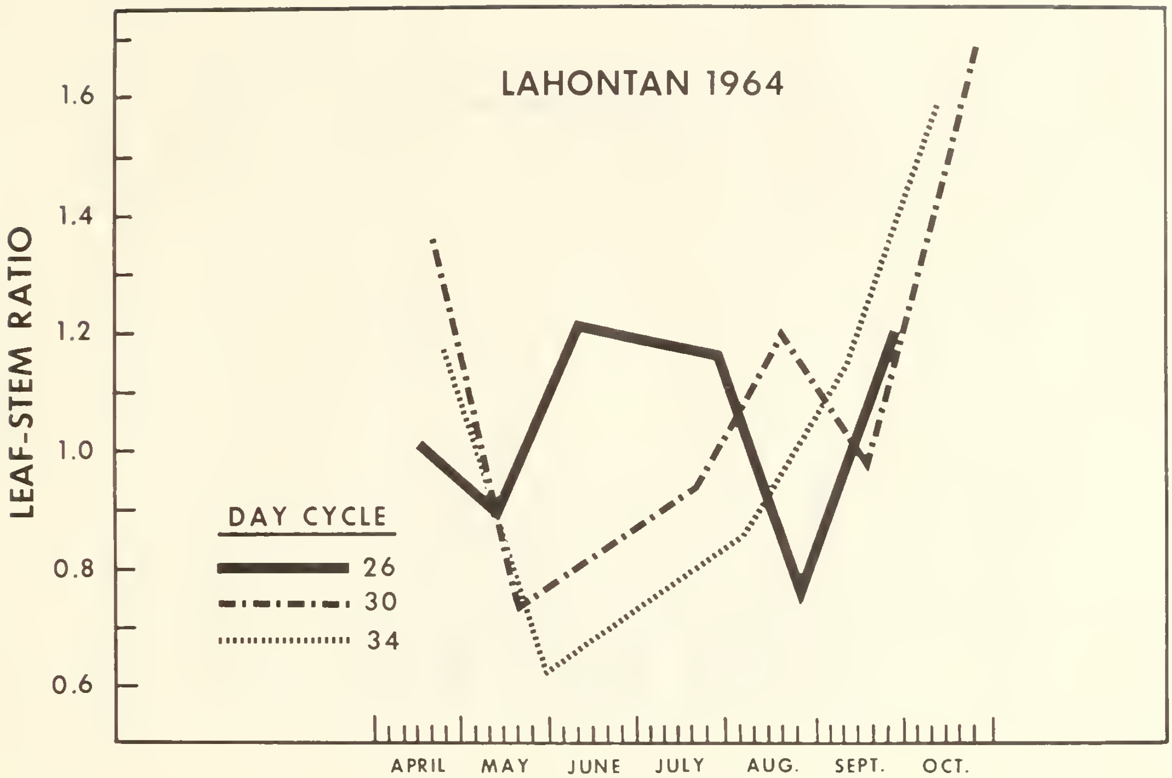

Figure 2.--Leaf-stem ratios of Lahontan alfalfa for three cutting cycles in 1964.

we obtained many samples of the commercial product of greatest volume in the dehydrating industry. These were meal made by regrinding pelleted material. We were also interested in observing how much variation occurred in dehydrated alfalfa as manufactured by various producers.

Eight 5-pound samples of reground pelleted meal, received from South Dakota, California, Ohio, Kansas, Nebraska, and Washington, contained information on the method of manufacture and content of additives, if any. Each lot was carefully cut down on a riffle to obtain a portion for proximate feed analysis and another portion for use in determining particle size distribution.

Wide variations appeared in the particle size distribution (figs. 3 and 4; also, appendix tables 20 and 21). Not only sieve separations but also sedimentation tests were made upon the material passing 200 mesh (74 microns). Three illustrations of the complete distribution curves are shown on logarithmic probability paper (fig. 4). The coarsest and the finest products are depicted with one intermediate.

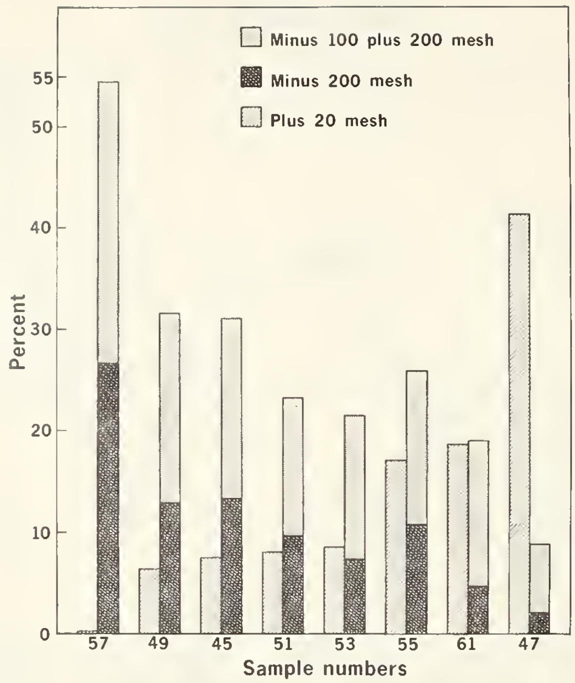

Figure 3.--Gross particle size distribution of eight commercial samples of reground pellet meal.

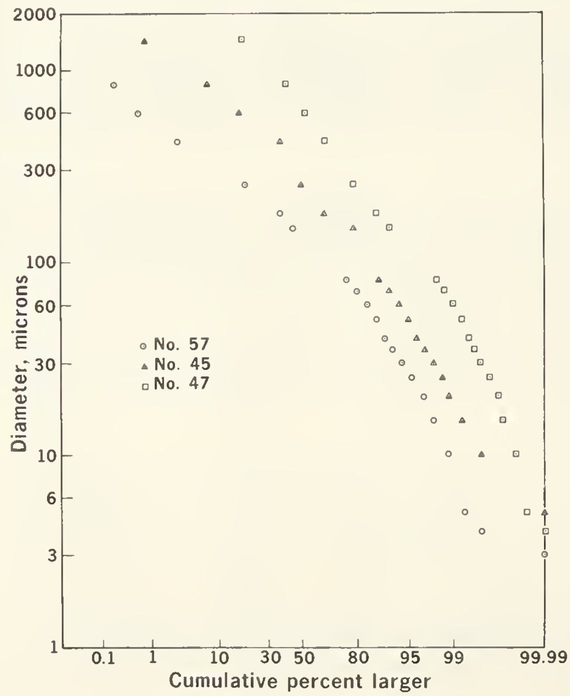

Figure 4.--Particle size distribution of three commercial samples of reground pellet meal.

Screen fractions were analyzed for total solids, crude protein, crude fiber, fat, and ash. Nitrogen-free extract was computed. Grit was run on the original samples and on some of the sieve fractions. Here again, variation between samples was wide.

In appendix table 20, sample 388-53, data show that approximately 33 pounds of abrasive grit is being ground in every ton of the product. This must exert a serious abrasive action on all moving parts and on piping and cyclone collectors.

Calling attention to appendix table 20, from data of sample 388-57, it would seem that a good separation designed to improve the product might be made by putting all the material over a 40-mesh screen. This would result in two fractions which, on a tonnage basis, would yield 1,612 pounds of a product of 20.86 percent protein and 24.93 percent fiber and 288 pounds with an analysis of only 11.69 percent protein and 42.17 percent fiber.

LARGE SCALE FRACTIONATION

Sifting

In 1963 and 1964 our efforts were confined to treatment of small samples obtained from various parts of the country to learn more about the ratio of leaf to stem in the varieties most commonly used at various stages of plant nutrition. We also made separations manually to determine distribution of chemical components in the various physical fractions of the alfalfa plant. These studies lent direction to further efforts on a commercial or semi-commercial scale, using mechanical equipment.

In 1963 through the cooperation of Archer-Daniels Midland Co., in Holcomb, Finney County, Kans., Nebraska Farm Products, Inc., in Cozad, Dawson County, Nebr., and Dixon Dryer Co., in Dixon, Solano County, Calif., we obtained large samples of each alfalfa cutting for the entire crop year. From Kansas we obtained Buffalo variety; from Nebraska, Ranger; and from California, both Lahontan and Moapa. Each lot was carefully sampled and proximate analysis made (table 6). Each was then given a light milling treatment in a Rietz Disintegrator with no screen and sifted on a Sweco Separator using two woven wire screens--8-mesh and 12-mesh. Previous experiments with greater varieties of screen openings had convinced us that either 8 or 12 mesh would be most suitable. Appendix tables 22

TABLE 6.--Analytical data and components distribution: Four varieties and two screen openings 1963

Screen size and variety	Cuttings	Feed		Fine fraction			Coarse fraction			Fine fraction improvement	
		Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber	Points protein	Points fiber
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Processed at 12 mesh:											
Lahontan	7	21.9	23.1	52.8	28.0	14.2	47.2	15.3	32.2	6.1	8.9
Moapa	5	19.9	26.1	47.7	27.6	15.5	52.3	13.0	35.7	7.7	10.6
Buffalo	5	20.5	20.6	46.5	24.7	12.9	53.5	16.5	27.4	4.2	7.7
Ranger	5	19.5	25.9	35.5	26.0	16.1	64.5	16.1	30.9	6.5	9.8
Average		20.5	23.9	45.6	26.6	14.7	54.4	15.2	31.8	6.1	9.2
Processed at 8 mesh:											
Lahontan	7	21.9	23.1	69.2	26.1	16.8	30.8	12.6	37.6	4.2	6.3
Moapa	5	19.9	26.1	65.5	24.8	19.0	34.5	10.7	39.4	4.9	7.1
Buffalo	5	20.5	20.6	69.0	23.7	15.0	31.0	13.1	33.0	3.2	5.6
Ranger	5	19.5	25.9	56.6	24.0	19.1	43.4	13.8	34.3	4.5	6.8
Average		20.5	23.9	65.1	24.6	17.5	34.9	12.5	36.1	4.1	6.4

through 26 give detailed results for each variety. While 20 percent more fines are collected at 8 mesh, it is done at a sacrifice of 2 percentage points of protein. When speaking of percentage points improvement, we mean the increase in protein and decrease in fiber in the fine fraction above that in the feed. All analyses given are on a 93-percent total solids basis.

During 1964 at Dixon, Calif., we sampled three adjacent alfalfa plots of about 15 acres each. These plots were so situated that their normal pattern of irrigation could be effected individually. The variety was Lahontan and the stands were 4 years old. We were making a study of the cutting cycle along with our fractionation. The three plots 1, 2, and 3 were harvested at 26-, 30-, and 34-day intervals, respectively (table 7). Tons per acre

TABLE 7.--Lahontan alfalfa from California, 1964 crop: Yield, distribution, and protein content of three cutting cycles

Alfalfa	26-day cycle Plot 1, 7 cuts		30-day cycle Plot 2, 7 cuts		34-day cycle Plot 3, 6 cuts	
	Tons per acre	Percent protein	Tons per acre	Percent protein	Tons per acre	Percent protein
Whole alfalfa	5.44	22.1	6.59	21.8	7.41	19.9
Fine	2.14	28.0	2.95	27.3	2.94	26.2
Coarse	3.29	16.9	3.64	16.3	4.47	14.2

increased with the greater time interval in cuttings and plot 3 had the highest total tons per acre although plot 3 was cut six times instead of seven as in plots 1 and 2. The tonnage of fine fraction per acre remained the same for plot 3 as for plot 2. The percent protein in fine fraction dropped 1 point for each 4-day lag in cutting although the percent protein in the whole meal dropped 0.3 percent from 1 to 2 but 1.9 percent from plot 2 to 3. Average improvement in fine fraction was 6.2 percentage points protein.

As work advances on composition and nutritional value of fractionated dehydrated alfalfa products, the greatest economic gain may be experienced by using the longer cutting cycle to obtain the greater total tonnage. Plot 3 required only six harvests, thereby harvesting costs were reduced by one-seventh. Moisture content of the raw alfalfa dropped 1 percent for each of the 4-day

intervals. In dropping the moisture content from 80 percent to 79 percent, there were 445 fewer pounds of water to evaporate to produce a ton of commercially dry alfalfa. This is a reduction of 6 percent water evaporation and would reduce fuel cost and increase throughput.

In 1965 both cutting cycle and separation by screening were studied. The work had two objectives: (1) To determine as well as we could the stage of growth of the Ranger variety under local Nebraska conditions for maximum use of the growing crop when it is dehydrated; and (2) to separate the dehydrated crop into two fractions--one for monogastric and one for ruminant animals. The two objectives are obviously somewhat interdependent. In the 1962 to 1964 tests, work had been confined to the laboratory, depending on samples collected at a distant dehydrator. In 1965 we had the advantage of dehydrating in our own small Arnold dryer figure 13 (see appendix) which was located on the premises of Nebraska Farm Products, Inc., in Cozad. This allowed us to control the entire process from harvesting through dehydrating, milling, and screening.

Nebraska Farm Products, Inc., provided a small field of Ranger alfalfa which was in its third year and doing well. We harvested second and third cuttings of a fixed area on each of four harvest dates, 28, 32, 36, and 40 days from previous harvest. All harvested material was weighed before and after dehydration and sifting.

Data covering total of second and third cuttings from this experiment are shown in tables 8, 9, and 10. Total alfalfa and total protein per acre increased markedly with time between cuttings.

As shown in figure 5 and table 10, a cutting cycle of somewhere near 36 to 40 days would be the best practice on second and third cuttings of Ranger alfalfa in the area of Cozad, Nebr. Total alfalfa protein, carotene, and xanthophyll all increased in total weight per acre between the 36- and 40-day plot although protein increase did not parallel that of alfalfa. Nothing seems to proliferate like crude fiber. It appears to increase in total weight about 1.7 percent per day between the 28-day and the 40-day plot in this experiment.

The quality of the whole alfalfa and of each fraction is of great interest in obtaining a high-protein, low-fiber fraction for poultry and swine. Table 11 shows the percentages of the whole by weight and their protein, fiber, carotene, and xanthophyll content.

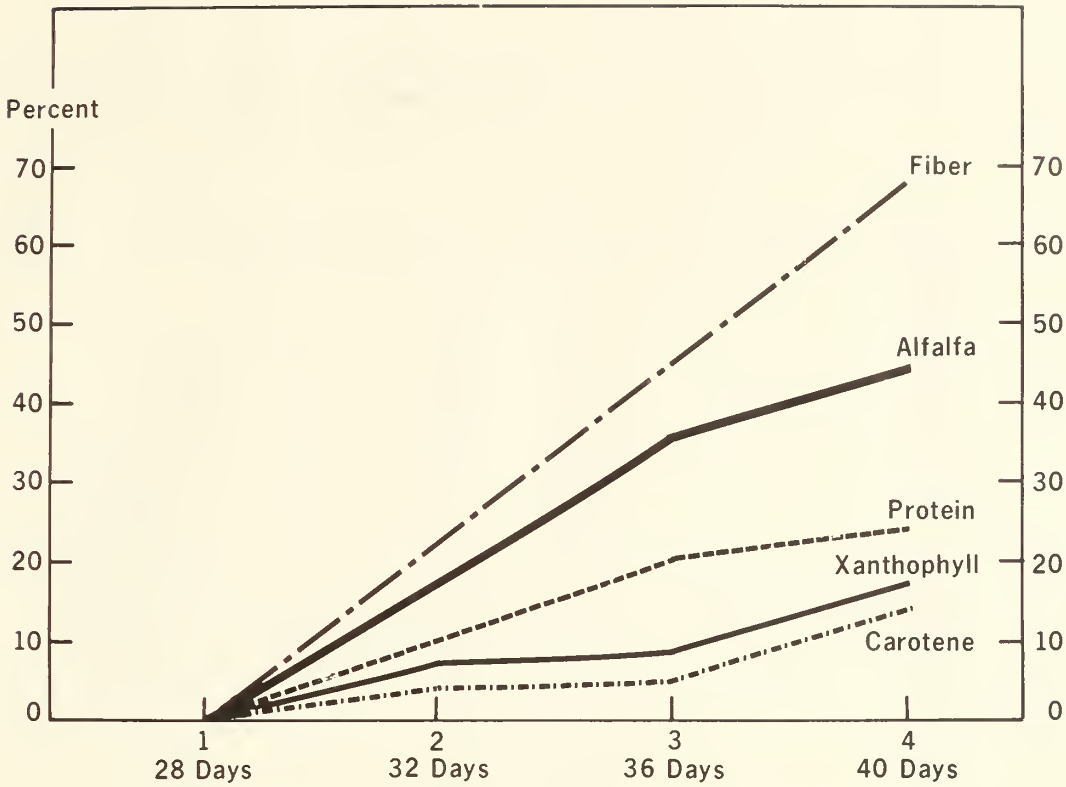

Figure 5.--Percent weight increase of Ranger alfalfa and some of its components with age.

From alfalfa of 18.5 percent protein, we made about one-half into a 25-percent protein grade and left about one-half as a 12-percent grade. By using screen openings of less than 6/64 inch, one can reduce the weight of the fine fraction to perhaps 25 percent of the whole. One can also improve the protein content of each fraction by leaving more of the stem protein with the coarse fraction and also leaving more of its fiber there. Until we are able to evaluate grades of alfalfa on their true values in feeding, including metabolizable energy and pigmenting ability, it will be impossible to state conclusively the worth of each grade in dollars. Appendix table 27 gives more detailed data.

Air Separation

In 1966 separation procedures were switched from screening devices to the use of an air separator. Through the courtesy of Stanford Research Institute, some preliminary work was done at their Pasadena Laboratory on a pilot model air separator of a design similar to a commercial machine manufactured by Scientific Separators, Inc., of

TABLE 8.--Per acre increase in production of Ranger alfalfa, Cozad, Nebr., 1965, and of protein as time interval increases

Plot No.	Number of days	Pounds alfalfa	Percent increase over previous plot	Pounds protein	Percent increase over previous plot
1	28	4,147	--	841	--
2	32	4,897	17	917	9
3	36	5,475	12	1,012	10
4	40	6,059	11	1,045	3
Cumulative increase		1,885	45	204	24

TABLE 9.--Per acre increases of Ranger alfalfa, Cozad, Nebr., 1965, for carotene and xanthophyll as time interval increases

Plot No.	Number of days	Grams carotene	Percent increase over previous plot	Grams xanthophyll	Percent increase over previous plot
1	28	422	--	507	--
2	32	440	4	546	8
3	36	444	1	552	1
4	40	480	8	595	8
Cumulative increase		58	14	88	17

TABLE 10.--Per acre effect of cutting cycle on yield of fiber of Ranger alfalfa, Cozad, Nebr.

Plot No.	Number of days	Pounds fiber	Percent increase over previous plot
1	28	1,133	--
2	32	1,388	23
3	36	1,629	17
4	40	1,905	17
Cumulative increase		772	68

TABLE 11.--Analytical data (combined second and third cuttings) of Ranger alfalfa, Cozad, Nebr., 1965

Alfalfa and Plot No.	Number of days	Weight	Protein	Fiber	Carotene	Xanthophyll
		Percent	Percent	Percent	mg./lb.	mg./lb.
Whole alfalfa:						
1	28	100	21.0	25.9	101	121
2	32	100	18.7	28.4	90	111
3	36	100	18.1	30.2	81	101
4	40	100	17.3	31.5	79	98
Weighted average		100	18.8	28.9	87	107
Fine fraction:						
1	28	57	26.6	16.7	158	176
2	32	50	25.1	17.9	137	158
3	36	50	25.2	17.5	128	150
4	40	48	24.5	18.0	131	148
Weighted average		50	25.3	17.6	138	157
Coarse fraction:						
1	28	43	13.8	37.7	47	68
2	32	50	12.5	38.6	43	65
3	36	50	11.8	43.8	35	52
4	40	52	10.6	43.6	32	53
Weighted average		50	12.0	40.9	38	58

of Denver, Colo. (see appendix). The pilot results were very encouraging and the Nebraska Department ordered a 4- by 24-inch commercial unit. This unit was expected to handle a load of 3,000 pounds of dehydrated alfalfa per hour just as it came from the cooling cyclone.

Through the cooperation of Shofstall Inc., of Odessa, Nebr., we were able to erect our equipment at the Odessa plant and were furnished alfalfa from one of their dehydrating units. We had many operating difficulties in Odessa, none of them attributable to our host company. All of our equipment was out of doors. Odessa is in an area of summer wind and rain. Make-do equipment for transfer of product was in cramped quarters, between two dehydrators. The original 4- by 24-inch separator column proved inadequate and was not equipped with any means of distribution across the 24-inch opening. Near the end of the alfalfa season the 4- by 24-inch column was replaced by a 4- by 50-inch column. Using a series of varying air velocities, we completed one good experimental run with the latter column. Convinced

that the air separation process would work, we successfully made several tons of 3/4-inch pellets from unground coarse fraction.

Based on the results at Odessa in 1966, we decided on further experiments in 1967. Facilities in a three-story building at the Darr, Nebr., plant of Platte Valley Products, Inc., gave us the advantage of having indoor operation and of gravity flow. This eliminated two of our chief troubles of 1966. Pellet mills and coolers already in place were an added advantage.

Tables 12 and 13 show the results obtained on 19.5-percent grade Ranger alfalfa. Seven different air velocities were used from 215 linear feet per minute (l.f.m.) up to 625 at a fairly uniform feed rate averaging 1,410 pounds per hour. At the lowest velocity (215 l.f.m.), we recovered 3 percent as fines analyzing 29-percent protein; at the highest velocity (625 l.f.m.), we recovered 40 percent as fines analyzing 27.4 percent.

The grade of the coarse fraction dropped to 15.0 percent protein at the highest velocity. Thus, from 5 tons of 19.5-percent protein dehy, we would recover 2 tons of 27 percent grade and 3 tons as a 15-percent grade. The American Dehydrator Association in late 1968 recommended the 15-percent grade for cattle feeding.

During the 1967 studies all of the coarse fractions were pelleted on a California Pellet Mill (CPM) flatbed pellet mill using a die that produced a wafer-type pellet of 1 inch by 1/2 inch and of varying lengths up to 2 inches. The pelleting was done with no prior grinding so that many fibrous pieces in the finished pellets were up to one-half inch long.

The 27-percent protein fine fraction shows a 50-percent improvement in carotene content and about 28-percent improvement in xanthophyll compared with the material fed.

To investigate the possibilities of the process when faced with very low grade alfalfa, we made runs at four velocities on material that averaged 13.4-percent protein (tables 14 and 15). At the highest velocity (550 l.f.m.), we recovered 26 percent of this as a 17.4-percent protein product with a lower than normal fiber content, 111 mg./lb. of carotene and 126 mg./lb. of xanthophyll.

TABLE 12.--Analytical data, product distribution and protein, and fiber concentration at various air velocities Ranger alfalfa, Darr, Nebr., 1967

Air velocity	Feed rate	Feed		Fine fraction			Coarse fraction		
		Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber
L.f.m.	L.f.m.	Percent	Percent	Percent	Percent	Percent		Percent	Percent
215	1,465	19.7	26.3	3.1	29.0	15.0	96.9	19.4	26.6
290	1,315	19.8	26.7	7.4	28.9	14.9	92.6	19.1	27.6
365	1,320	19.2	27.7	14.2	29.3	14.6	85.8	17.6	29.8
425	1,515	18.6	29.1	18.8	29.0	14.7	81.2	16.2	32.5
500	1,395	20.1	26.1	25.8	27.8	14.5	74.2	17.5	30.1
550	1,505	19.2	32.7	33.2	27.3	17.2	66.8	15.2	40.5
625	1,350	19.9	26.9	40.0	27.4	17.1	60.0	15.0	33.4
Average	1,410	19.5	27.9	--	--	--	--	--	--

Air velocity	Feed rate	Fine fraction recovery of --		Percentage points improvement in --		Improvement of --	
		Protein	Fiber	Protein	Fiber	Protein content	Fiber content
		Percent	Percent			Percent	Percent
215	1,465	4.4	1.8	9.3	11.3	47.2	43.0
290	1,315	10.9	4.1	9.1	11.8	46.0	44.2
365	1,320	21.6	7.5	10.1	13.1	52.6	47.3
425	1,515	29.2	9.5	10.4	14.4	55.9	49.5
500	1,395	35.6	14.3	7.7	11.6	38.3	44.4
550	1,505	47.0	17.5	8.1	15.5	42.2	47.4
625	1,350	54.9	25.4	7.5	9.8	37.7	36.4

Table 13.--Analytical data, product and component distribution, and concentration of carotene and xanthophyll at varying air velocities, Ranger alfalfa, Darr, Nebr., 1967

		Feed		Fine fraction			Coarse fraction		
Velocity	Rate	Carotene	Xanthophyll	Weight	Carotene	Xanthophyll	Weight	Carotene	Xanthophyll
L.f.m.	Lb./hr.	Mg./lb.	Mg./lb.	Percent	Mg./lb.	Mg./lb.	Percent	Mg./lb.	Mg./lb.
215	1,465	101.7	140.2	3.1	147.4	174.6	96.9	100.2	139.1
290	1,315	104.6	141.6	7.4	161.0	200.6	92.6	100.2	136.9
365	1,320	95.8	129.2	14.2	160.4	179.7	85.5	85.1	120.8
425	1,515	82.1	98.5	18.8	154.9	159.0	81.2	65.2	84.5
500	1,395	98.3	134.5	25.8	153.8	172.3	74.2	79.0	121.3
550	1,505	91.1	116.5	33.2	150.7	167.9	66.8	61.5	91.0
625	1,350	89.0	106.5	40.0	133.6	135.8	60.0	59.3	87.0
Average	1,410	94.6	123.9	--	--	--	--	--	--

		Fine fraction percent recovery of --		Improvement of --			
		Carotene	Xanthophyll	Carotene content	Xanthophyll content	Carotene content	Xanthophyll content
				Mg./lb.	Mg./lb.	Percent	Percent
215	1,465	4.6	3.9	45.7	34.4	44.9	24.9
290	1,315	11.6	10.5	56.4	59.0	53.9	41.7
365	1,320	23.8	19.8	64.6	50.5	67.4	39.1
425	1,515	35.5	30.3	72.8	60.5	88.7	61.4
500	1,395	40.4	33.2	55.5	37.8	56.5	28.1
550	1,505	54.9	47.8	59.6	51.4	65.4	44.1
625	1,350	60.0	51.0	44.6	29.3	49.8	27.5

Table 14.--Analytical data, product and component distribution, and protein and fiber concentration at varying air velocities, Ranger alfalfa, Darr, Nebr., 1967

Air velocity	Feed rate	Feed		Fine fraction			Coarse fraction		
		Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber
L.f.m.	Lb./hr.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
365	1,340	14.8	27.5	14.9	20.4	19.0	85.1	13.8	28.9
425	1,815	13.9	29.1	14.0	20.2	17.6	86.0	12.8	31.0
500	1,320	13.2	30.3	22.7	18.9	21.0	77.3	11.5	33.0
550	1,590	11.9	30.7	26.4	17.4	21.8	73.6	9.9	33.9
Average	1,515	13.4	29.4	--	--	--	--	--	--

Air velocity	Feed rate	Fine fraction percent recovery of--		Percentage points improvement		Improvement of--	
		Protein	Fiber	Protein	Fiber	Protein content	Fiber content
						Percent	Percent
365	1,340	20.5	10.3	5.6	8.5	37.8	44.7
425	1,815	20.4	8.5	6.3	11.5	45.3	65.3
500	1,320	32.6	15.7	5.7	9.3	43.2	44.3
550	1,590	38.5	18.7	5.5	8.9	46.2	40.8

Table 15.--Analytical data, product and component distribution, and carotene and xanthophyll concentration at varying air velocities, Ranger alfalfa, Darr, Nebr., 1967

Air velocity	Feed rate	Feed		Fine fraction			Coarse fraction		
		Carotene	Xanthophyll	Weight	Carotene	Xanthophyll	Weight	Carotene	Xanthophyll
L.f.m.	Lb./hr.	Mg./lb.	Mg./lb.	Percent	Mg./lb.	Mg./lb.	Percent	Mg./lb.	Mg./lb.
365	1,340	71.9	96.8	14.9	104.3	110.1	85.1	66.2	94.5
425	1,815	66.2	93.2	14.0	123.0	148.4	86.0	56.9	84.2
500	1,320	68.8	99.6	22.7	118.0	139.3	77.3	54.3	87.9
550	1,590	64.9	88.1	26.4	110.8	126.4	73.6	48.5	74.3
Average	1,515	67.9	94.4	--	--	--	--	--	--

Air velocity	Feed rate	Fine fraction percent recovery of--		Improvement of--			
		Carotene	Xanthophyll	Carotene	Xanthophyll	Carotene	Xanthophyll
				Mg./lb.	Mg./lb.	Percent	Percent
365	1,340	21.7	16.9	32.4	13.2	45.1	13.6
425	1,815	26.1	22.3	56.8	55.2	85.8	59.2
500	1,320	39.0	31.8	49.2	39.7	71.5	39.8
550	1,590	44.9	38.0	45.9	38.3	70.7	43.5

In the 1967 experiments velocities over 700 resulted in loss of fines through the blower, regardless of the feed rate. Also, similar losses were encountered at lower velocities when feed rate was stepped up. This seemed to us to indicate need for a larger cyclone separator. We wanted to use velocities higher than 700 and higher feed rate.

In the 1968 experiments at Darr, Nebr., we installed a cyclone separator of 29-1/4 inch diameter to replace the 20-inch one and replaced the 3 hp. motor on the blower with a 5 hp. motor. We pelleted all unground coarse fraction in either 3/4 inch square pellets or about 1-3/8 by 3/4 inch wafer-type pellets. We also pelleted unground fine fraction using a one-fourth inch die. No particular trouble was experienced in pelleting either fraction except when there were wide fluctuations of moisture content of the chops. Once produced, the pellet quality remained high during storage and shipment.

The 1968 operations did bring to our attention the importance of rate of feed with relation to the degree of upgrading the fine fraction. By plotting the percentage points of protein improvement in the fine fraction at 83 points of feed rate (fig. 6), we were able to draw a

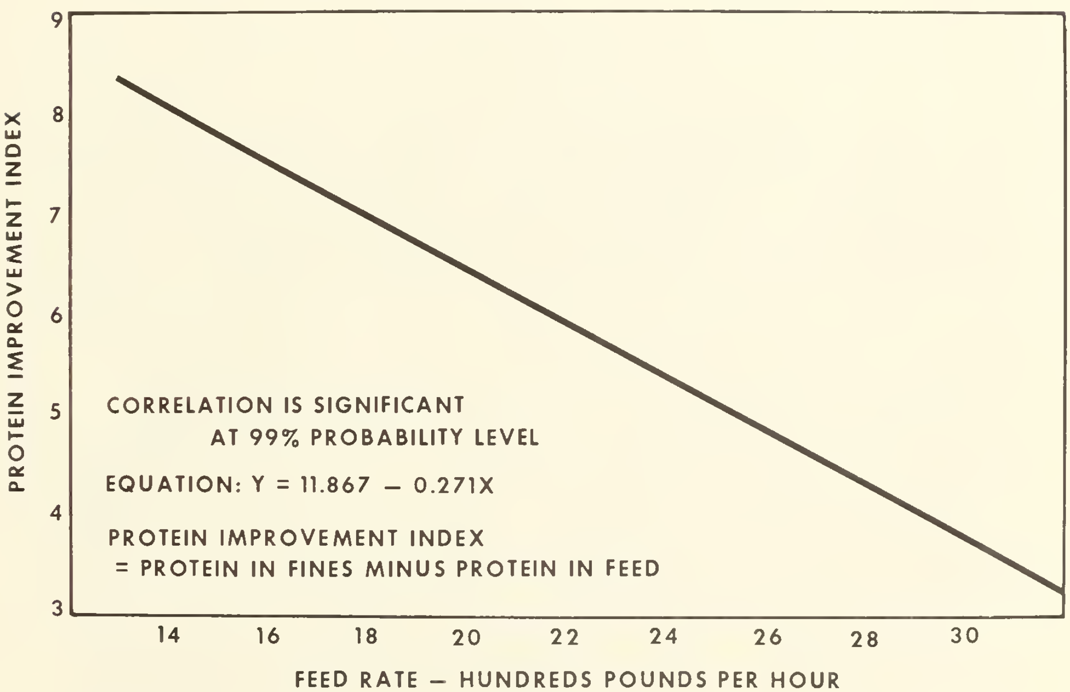

Figure 6.--Regression line showing relationship of feed rate to quality improvement in air separation fine fraction of alfalfa.

regression line with a correlation probability of 99 percent. From this regression line, at 1,400 pounds per hour, we could expect about 8 percentage points protein improvement while at 2,700 pounds per hour this was cut in half to 4 points. At 2,200 pounds per hour 6 points' improvement is indicated. We conclude that this 4- by 50-inch column should be rated at about a ton to a ton and a quarter for reasonable separation potential. For higher tonnages, we recommend the 4-inch dimension be increased to 6 inches, and the blower and its motor be enlarged. Our experience has been limited to the one 4- by 50-inch column.

The average of 16 runs on whole alfalfa chops at an average feed rate of 2,455 pounds per hour and 730 linear feet per minute (l.f.m.), points improvement was 4.43.

We have made available large quantities of loose and pelleted coarse fractions from both scalping and air separation to Purdue University, Texas A&M University, Kansas State University, University of Nebraska, University of Illinois, South Dakota State University, and Agway, Inc. These lots were to be used in feeding sheep, beef cattle, dairy cows, dairy calves, and horses. Most of the coarse fraction was in large pellet form, 3/4 inch square, 1 3/8 by 3/4-inch flat wafers, or 1 inch by 1/2 inch wafer-type pellets. In all cases the coarse alfalfa was not ground before pelleting.

DISCUSSION

The separation of whole alfalfa chops into two fractions is entirely feasible by either of two methods: (1) Scalping on a shaking screen surface or (2) air separation by using controlled velocity air currents in a specially designed closed system apparatus.[8,9]

In the positive air type of dehydrator, where the product passes through the fan, there is fairly good breakdown of the leaves and separation of leaves from petioles. In the negative air type of dehydrator, where product never enters the fan, no such breaking is encountered.

8/ Chrisman, Joseph, Kohler, George O., and Smith, Kenneth, V. Alfalfa separation variables. Nebraska Alfalfa Dehydrators Association Meeting, Lincoln, Nebr. 1969.

9/ Chrisman, Joseph, and Kohler, George O. Air separation procedures. Nebraska Alfalfa Dehydrators Association Meeting, Lincoln, Nebr. 1968.

Therefore, when separating by either air or sifting is attempted, the negative system will require an additional unit such as a Rietz Disintegrator to condition the product. Even with the positive air-type of dehydrator, some advantage can be gained in a further breakdown. Our mobile unit (see appendix) was equipped with a Rietz disintegrator for this purpose. This disintegrator is a vertical hammer mill with rigid hammers. We did not use a screen, only the beating action of the hammers.

Appendix, tables 22 through 26 present data on "Processed" and "Unprocessed." Processed indicates that the material was passed through this disintegrator before separation procedures; unprocessed denotes no additional breaking action was used.

It should be emphasized that moisture content of the product as dehy comes from the dehydrator will be important. It is of advantage to obtain the highest moisture content compatible with otherwise good operation which will result in tough stems, not easily broken while the leaves will be dry and friable. Another advantage of high moisture product in separating by air is the higher density of the coarse fraction. An additional advantage of high moisture is in demonstratably higher xanthophyll retention (9,10).

The degree of improvement in quality of the fine or light fraction in a scalping operation will be determined to a large extent by two factors--(1) the quality of the input or feed and (2) the size of opening in the screen surface (see table 6). The amount in the fine fraction will depend mostly on the size of screen opening. Some operators might prefer, and this is feasible, to use a scalper dressed with two different sized screen openings. The primary having the smaller openings will give a product several percentage points of protein higher than that from the larger opening secondary screen.

In air separation, the weight of fine fraction, or its percentage of the whole, is determined by the air velocity used provided the air separator column is not overloaded. However, the quality of the fine fraction, as judged by its protein content, under conditions of constant "no overload," will not drop appreciably until velocity of the air is raised above 500 to 700 linear feet per minute. Quality of the coarse fraction, however, may be lowered with each velocity step. This is because more "pure leaf" is being brought over with each velocity increase until at 500 to 700 l.f.m. one has pulled most free leaf over and

begins to pull small fibrous parts of stems as well. Beyond that point, variation in quality of each fraction will change gradually until at some point, which we have not yet determined precisely, the fiber content will again exceed the protein content as it did in the whole alfalfa. This velocity point will probably not be the same for all grades and conditions of feed. Figure 7 and table 16 show

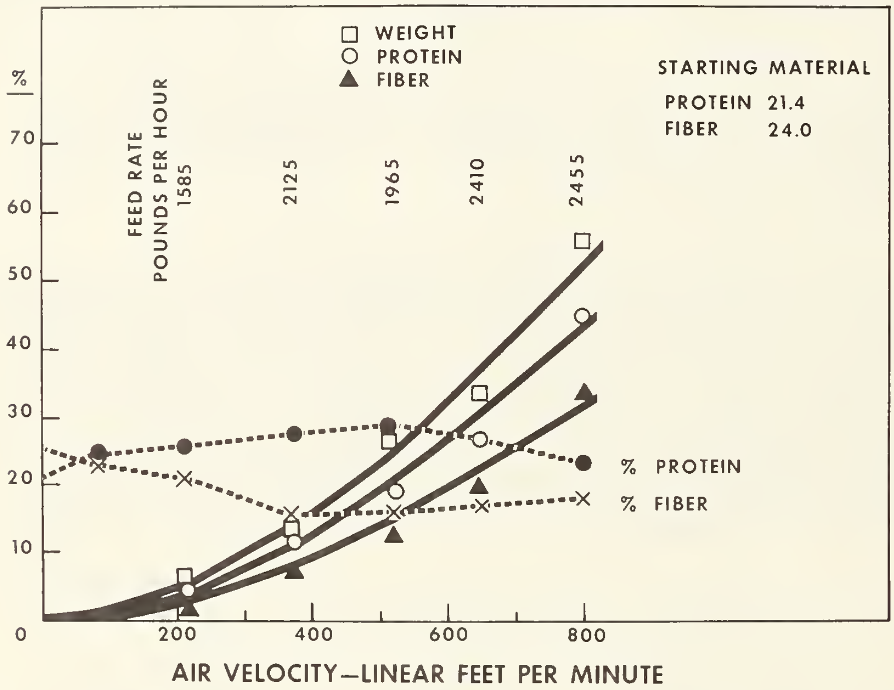

Figure 7.--Percent recovery and composition--fine fraction.

the trend we mention, although they are not a perfect exposition of this point. The solid line curves in figure 7 denote the percent recovery in the fine fraction of weight, protein, and fiber in descending order. The dotted lines show the actual protein and fiber values in the fine fractions.

Air separation is much more easily adjusted to vary the weight and quality of fractions during operation than is scalping, requiring only the adjustment of the valve on the blower outlet to change velocity in the column.

Like a number of other processing operations, by continuous practice, an operator will become familiar with what is occurring in the machine and will know what

Table 16.--Analytical data, product and component distribution at varying air velocities, Ranger alfalfa, Darr, Nebr., 1968

Velocity	Feed rate	Feed		Fine fraction			Coarse fraction		
		Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber
L.f.m.	Lb./hr.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
215	1,585	21.0	24.3	4.3	25.5	21.5	95.7	20.5	24.5
370	2,125	22.0	23.1	11.3	27.7	16.0	88.7	21.3	24.1
520	1,965	21.0	24.5	19.8	26.9	16.0	80.2	19.5	25.6
645	2,455	21.0	24.7	44.9	25.6	18.2	55.1	17.3	29.9
Average	2,110	21.4	24.0	--	--	--	--	--	--

Velocity	Feed rate	Fine fraction percent recovery		Percentage points improvement		Percent improvement	
		Protein	Fiber	Protein	Fiber	Protein	Fiber
215	1,585	5.2	3.8	4.5	2.8	21.4	11.5
370	2,125	14.2	7.8	5.7	7.1	25.9	30.7
520	1,965	25.3	13.0	5.9	8.5	28.1	34.7
645	2,410	54.6	33.1	5.0	6.4	22.5	27.6
800	2,455	--	--	4.6	6.5	21.9	26.3

adjustments are needed to obtain the desired end products. Certainly, the operator of a dehydrator knows this and realizes that his operation must be modified to suit variations in the loads of green chop from the lush early first cutting to the mature relatively dry cuttings of July or August. A good operator knows how to cope with these variations and will soon learn how to handle and adjust his separator.

A good experienced fieldman at a dehydrator can usually tell within 1 or 2 percent of protein what grade of alfalfa he is about to harvest. The plant manager or superintendent will be advised of what grades are needed. By using a nomograph similar to figure 8, he can tell

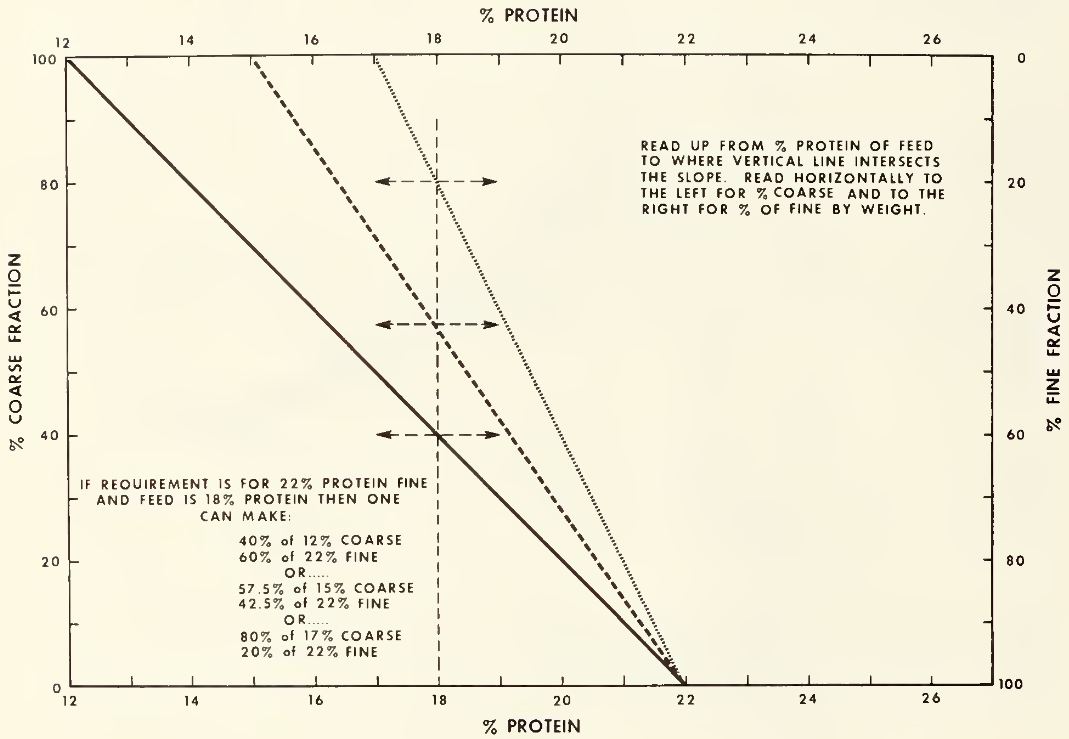

Figure 8.--Nomograph for determining percent of each of two fractions by weight.

approximately what percentage of each grade can be made from a known quality of raw feed. Such a nomograph is a good guide to operation. In this illustration we assume the plant is operating on 18-percent protein alfalfa. Assuming the need is for 22-percent upper grade and 15-percent lower grade, we draw a line from the 22-percent point to the lower right to the 15-percent point on the upper left. Where that line intercepts the vertical line

at 18, one can read to the left for percent by weight of the lower grade and to the right for the percent of the higher grade, which is 57.5 and 42.5 percent, respectively.

ECONOMIC EVALUATION

Carl J. Vosloh, Jr., of Economic Research Service, USDA made a very thorough study of the costs and capital requirements associated with air separation in alfalfa dehydrating plants. His findings have been reported in Marketing Research Report No. 881, ERS, USDA (16). Mr. Vosloh's summary of the study reads as follows:

"Separating alfalfa leaf and stem into high-protein feed for hogs and poultry and high-fiber feeds for cattle appears economically feasible. Having more nutrients available per ton and extending the alfalfa cutting season should offset the slight added cost of separation--$0.30 to $3.24, depending on scale of operations.

"Costs of the new separation process were synthesized for six model dehydrating plants, using the economic-engineering technique. The standard models represent six evaporative drum capacities ranging from 10,000 to 33,000 pounds of water an hour.

"Investment costs for the standard models--without separation--ranged from $190,200 for the smallest plant, producing 4,950 tons a year, to $321,400 for one producing 17,325 tons. Investment per ton of annual capacity ranged from $38.42 to $18.55. Annual operating costs dropped from $18.37 a ton for the smallest plant to $11.01 for the largest. Fixed costs varied in the same ratio from 33 to 24 percent of the total cost of production. As hourly output increased from 1 1/2 to 5 1/4 tons, the total cost decreased 40 percent.

"Equipment and facilities for separation increased model costs by $64,000 to $81,500. Three alternative systems for each of the six models allowed comparison of 18 operations, all sufficiently different to change equipment requirements and costs.

"Dehydration and separation costs were highest in the smallest model--$21.61 a ton. The largest model cost least--$11.31 a ton. Separation added between $1.70 to $3.24 a ton over the standard model costs in the smallest group. In the largest volume group, separation increased the cost between $0.30 to $1.03 a ton.

"Because dehydrated alfalfa is unstable under ordinary storage conditions, alfalfa dehydrators increasingly use inert gas storage to preserve product quality. Storage costs, including those for inert gas, for standard models ranged from $7.49 a ton in the smallest model to $5.40 in the largest. Models separating alfalfa had slightly higher costs for additional storage facilities and conveying equipment--$7.69 for the smallest and $5.69 for the largest.

"Combining all costs allowed calculation of the total cost per ton. The most efficient separation model increased the total cost per ton between $1.81 to $0.47 over the standard model costs of $22.87 and $14.25. The highest cost separation model increased the per ton cost between $3.35 and $1.20."

ADVANTAGES TO THE DEHYDRATOR IN USING AIR SEPARATION

Deficiencies in protein in meeting grade guarantees are probably very few today. However, we believe the delivery of excess protein, particularly among those producers who attempt to market directly as they manufacture, amounts to a considerable tonnage.

Air separation would help to eliminate these "give aways." A simple instance might be that of a producer servicing a feedlot with 15-percent protein and meeting a 17-percent protein market for shipment over the gateway. When operating in a field of 16-percent grade, he will have to allocate the entire tonnage to feedlot sales. However, by using air separation one can split the tonnage into one-half at 17 percent and one-half at 15 percent, thereby servicing both markets.

A similar situation might be cited where the desire is to service two outlets--one at 17-percent grade and one at 20 percent. If operating from a field of 19 percent, the whole tonnage would have to be called 17 percent to meet the guarantee. With air separation, about two-thirds of the tonnage could be converted to 20-percent grade and about one-third to 17-percent grade, thus making full use of the protein in marketing.

Tables 17, 18, and 19 derived from the use of the nomograph (fig. 8) show in percentage figures the weight distribution which can be obtained when whole dehydrated alfalfa of 10 different protein grades is air separated. The low quality of coarse fraction is fixed at 13-, 15-, or 17-percent protein, respectively.

Table 17.--Weight distribution in air separation of whole dehydrated alfalfa of 10 different proteins when the low quality of coarse fraction is fixed at 13-percent protein

Percent of protein of whole alfalfa	Percent of-- 25 pct grade	13 pct grade	22 pct grade	13 pct grade	20 pct grade	13 pct grade	18 pct grade	13 pct grade	17 pct grade	13 pct grade
14	8.5	91.5	11.5	88.5	15.0	85.0	20.0	80.0	25.0	75.0
15	17.0	83.0	22.5	77.5	29.0	71.0	40.0	60.0	56.5	43.5
16	25.0	75.0	33.5	66.5	43.0	57.0	60.0	40.0	75.0	25.0
17	33.5	66.5	45.0	55.0	57.5	42.5	80.0	20.0	--	--
18	42.0	58.0	56.0	44.0	71.5	28.5	--	--	--	--
19	50.0	50.0	66.5	33.5	86.0	14.0	--	--	--	--
20	58.5	41.5	78.0	22.0	--	--	--	--	--	--
21	67.0	33.0	89.0	11.0	--	--	--	--	--	--
22	75.0	25.0	--	--	--	--	--	--	--	--
23	83.5	16.5	--	--	--	--	--	--	--	--

Table 18.--Weight distribution in air separation of whole dehydrated alfalfa of 10 different protein grades when the low-quality of coarse fraction is fixed at 15-percent protein

Percent of protein of whole alfalfa	Percent of-- 25 pct grade	15 pct grade	22 pct grade	15 pct grade	20 pct grade	15 pct grade	18 pct grade	15 pct grade	17 pct grade	15 pct grade
14	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--
16	10.0	90.0	14.5	85.5	20.0	80.0	33.5	66.5	50.0	50.0
17	20.0	80.0	28.5	71.5	40.0	60.0	67.5	32.5	--	--
18	30.0	70.0	43.0	57.0	60.0	40.0	--	--	--	--
19	40.0	60.0	57.5	42.5	80.0	20.0	--	--	--	--
20	50.0	50.0	71.0	29.0	--	--	--	--	--	--
21	60.0	40.0	86.0	14.0	--	--	--	--	--	--
22	70.0	30.0	--	--	--	--	--	--	--	--
23	80.0	20.0	--	--	--	--	--	--	--	--

Table 19.--Weight distribution in air separation of whole dehydrated alfalfa of 10 different protein grades when the low quality of coarse protein is fixed at 17-percent protein

Percent of protein of whole alfalfa	Percent of							
	25 pct grade	17 pct grade	22 pct grade	17 pct grade	20 pct grade	17 pct grade	18 pct grade	17 pct grade
14	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--
18	12.5	87.5	20.0	80.0	33.0	67.0	--	--
19	25.0	75.0	40.0	60.0	67.5	32.5	--	--
20	37.5	62.5	60.0	40.0	--	--	--	--
21	50.0	50.0	80.0	20.0	--	--	--	--
22	62.5	37.5	--	--	--	--	--	--
23	75.0	25.0	--	--	--	--	--	--

Let us suppose that the annual production from the fields of a 10,000 ton plant is of the following rounded tonnages of protein grades:

	Tons
10 percent of 15 protein grade	1,000
20 percent of 16 protein grade	2,000
40 percent of 17 protein grade	4,000
10 percent of 18 protein grade	1,000
10 percent of 19 protein grade	1,000
10 percent of 20 protein grade	1,000
100 percent of 17.2 protein grade	10,000

If the market for this dehydrator is solely for 17 percent protein, evidently the producer should be able to supply 10,000 tons; but the timing of production of the various grades may easily put him in a position to make orderly deliveries very difficult if not impossible. He may find himself giving away considerable protein part of the time, making it impossible to use that protein in blending out some of the lower grades to the 17-percent standard. By using air separation, those adverse factors can be alleviated.

Example 1:

By air separating the 1,000 tons of 18 percent, he can produce 667 tons of 17 percent and 333 tons of 20 percent.

By air separating the 1,000 tons of 19 percent, he can produce 325 tons of 17 percent and 675 tons of 20 percent.

By air separating the 1,000 tons of 20 percent he can produce 400 tons of 17 percent and 600 tons of 22 percent.

This processing will result in:

Tons	
4,000	17 percent field run
667	17 percent recovered from 18 percent
325	17 percent recovered from 19 percent
400	17 percent recovered from 20 percent
5,392	

By blending the other lots, he will have:

Tons	
1,000	15 percent protein grade field run
2,000	16 percent protein grade field run
333	20 percent protein grade recovered from 18 percent
675	20 percent protein grade recovered from 19 percent
600	22 percent protein grade recovered from 20 percent
4,608	17.4 percent

Example 2:

Another example might be for the dehydrator who has established a cattle feedlot market for 15-percent protein grade and who wishes to produce both 17 percent and 20 percent for feed manufacturers market. Using the same field production, he can produce:

	Tons
10 percent of 15 percent protein grade	1,000
20 percent of 16 percent protein grade	2,000
40 percent of 17 percent protein grade	4,000
10 percent of 18 percent protein grade	1,000
10 percent of 19 percent protein grade	1,000
10 percent of 20 percent protein grade	1,000
100 percent	10,000

By air separating the 2,000 tons of 16 percent, he can produce 1,000 tons of 15 percent and 1,000 tons of 17 percent.

By air separating the 1,000 tons of 18 percent, he can produce 400 tons of 15 percent and 600 tons of 20 percent.

By air separating the 1,000 tons of 19 percent, he can produce 325 tons of 17 percent and 675 tons of 20 percent. Thus, he will have

Tons	
1,000	of 15 percent field run
1,000	of 15 percent recovered from 16 percent
400	of 15 percent recovered from 18 percent
2,400	

Tons	
4,000	of 17 percent field run
1,000	of 17 percent recovered from 16 percent
325	of 17 percent recovered from 19 percent
5,325	
1,000	of 20 percent field run
600	of 20 percent recovered from 18 percent
675	of 20 percent recovered from 19 percent
2,275	

No blending is required and no protein given away, and his total production is as follows:

	Tons
15 percent protein	2,400
17 percent protein	5,325
20 percent protein	2,275
	10,000

Example 3:

Let us assume a different distribution and a little higher average quality annual production as follows:

	Tons
5 percent of 15 percent protein grade	500
10 percent of 16 percent protein grade	1,000
30 percent of 17 percent protein grade	3,000
20 percent of 18 percent protein grade	2,000
10 percent of 19 percent protein grade	1,000
10 percent of 20 percent protein grade	1,000
10 percent of 21 percent protein grade	1,000
5 percent of 22 percent protein grade	500
100 percent of 18.15 percent grade	10,000

Let us suppose he wants to market only 17 percent grade and 22 percent grade. By air separating the 2,000 tons of 18 percent grade, he can produce 1,600 tons of 17 percent grade and 400 tons of 22 percent grade.

By air separating the 1,000 tons of 19 percent grade, he can produce 600 tons of 17 percent grade and 400 tons of 22 percent grade.

By air separating the 1,000 tons of 20 percent grade, he can produce 400 tons of 17 percent grade and 600 tons of 22 percent grade.

By air separating the 1,000 tons of 21 percent grade, he can produce 200 tons of 17 percent grade and 800 tons of 22 percent grade.

This processing will result in the following tonnages:

Tons	
3,000	of 17 percent protein grade field run
1,600	of 17 percent protein grade recovered from 18 percent
600	of 17 percent protein grade recovered from 19 percent
400	of 17 percent protein grade recovered from 20 percent
200	of 17 percent protein grade recovered from 21 percent
5,800	

Tons	
500	of 22 percent protein grade field fun
400	of 22 percent protein grade recovered from 18 percent
400	of 22 percent protein grade recovered from 19 percent
600	of 22 percent protein grade recovered from 20 percent
800	of 22 percent protein grade recovered from 21 percent
2,700	

By blending the 500 tons of 15 percent, the 1,000 tons of 16 percent and 500 tons of the 22 percent, the tonnage of 17 percent can be increased to 7,800 tons and the tonnage of 22 percent reduced to 2,200 tons if that would better suit the sales patterns. Otherwise, an outlet would have to be found for 1,500 tons of material averaging 15.5 percent protein.

Example 4:

Again let us assume the aim is all of the 17-percent possible with a cushion of high quality which might be blended with purchased lower grade, or sold as a premium product.

By air separating the 2,000 tons of 18 percent grade, he can produce 1,750 tons of 17 percent grade and 250 tons of 25 percent grade.

By air separating the 1,000 tons of 19 percent grade, he can produce 750 tons of 17 percent grade and 250 tons of 25 percent grade.

By air separating the 1,000 tons of 20 percent grade, he can produce 625 tons of 17 percent grade and 375 tons of 25 percent grade.

By air separating the 1,000 tons of 21 percent grade, he can produce 500 tons of 17 percent grade and 500 tons of 25 percent grade.

By air separating the 500 tons of 22 percent grade, he can produce 188 tons of 17 percent grade and 312 tons of 25 percent grade.

By blending the 500 tons of 15 percent grade, and the 1,000 tons of 16 percent grade with 250 tons of the 25 percent grade, he can produce 1,750 tons of 17 percent grade and have remaining 1,437 tons of 25 percent grade.

Thus, we wind up with:

Ton	
8,563	of 17 percent grade
1,437	of 25 percent grade
10,000	

The 1,437 tons of 25 percent grade will blend out at 17 percent with 5,748 tons of 15 percent to give a final plant total of 15,748 tons of 17 percent grade.

Numerous examples could be shown demonstrating the way air separation can be of help to the dehydrator. The dehydrator himself can best determine how the procedure can be suited to his own particular production schedule and marketing pattern by referring to tables 17, 18, and 19.

By using an enlarged nomograph similar to figure 8, he can greatly broaden the scope of his calculation to determine amounts of high- and low-protein fractions from any given starting material.

Use of air separation offsets to some extent, adverse weather conditions that have resulted in fields deteriorating in quality because they couldn't be harvested. Very often this results in the field being given over to sun curing with its inherent risks of inferior hay, or even in extreme cases, total loss. Even at 14-percent protein, one-fourth of the crop can be recovered as 17 percent by dehydrating and air separating with the other three-fourths running 13 percent for cattle feed.

Particularly in areas of very low weather hazards a longer cutting cycle and a greater total tonnage would be advantageous when separation procedures and equipment are

used. This is illustrated by the results shown in table 7 (p. 19) when sifting was used on alfalfa from Dixon, Calif., and in tables 8 through 11 (pp. 22, 23) when sifters were used at Cozad, Nebr.

The question might be raised as to whether a specific protein grade of either coarse or fine fraction is significantly different in its fiber content from the same protein grade of whole dehydrated alfalfa.

We have plotted 124 points from analyses made in this laboratory of samples from both California and Nebraska--protein ranging from 13.6 to 28.3 percent and fibers, from 16.7 to 34.5 percent. Figure 9 shows the regression line and confidence levels at 95 percent.

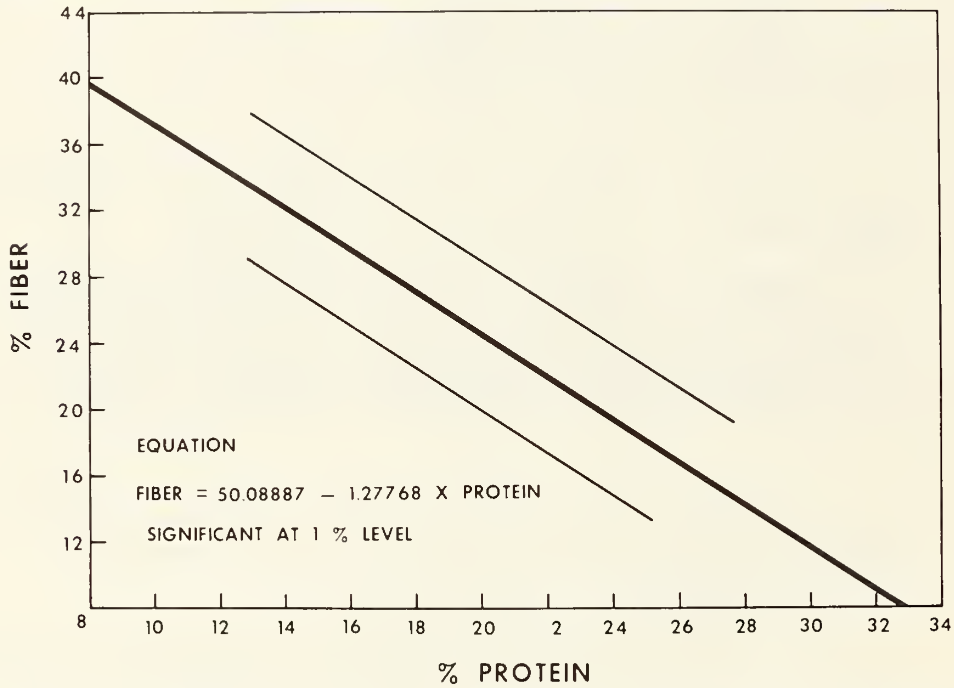

Figure 9.--Regression line of combined Nebraska and California whole alfalfa 124 points.

A similar treatment is shown in figure 10 where 205 points from analyses made in this laboratory on coarse and fine fractions from the 1967 and 1968 operations at Darr, Nebr., were used.

For comparative purposes, we tabulated the fibers for six protein grades as calculated from the regression equations:

Percent protein	Whole alfalfa dehy percent fiber	Coarse plus fine fractions-dehy percent fiber
13	33.48 ± 0.96	34.47 ± 0.96
15	30.92 ± 0.73	31.63 ± 0.73
17	28.37 ± 0.53	28.80 + 0.34
20	24.54 ± 0.40	24.54 ± 0.36
22	21.98 ± 0.50	21.71 ± 0.42
25	18.15 ± 0.80	17.46 ± 0.56

The increase in value of alfalfa products with increase of quality (as judged by protein content) is well

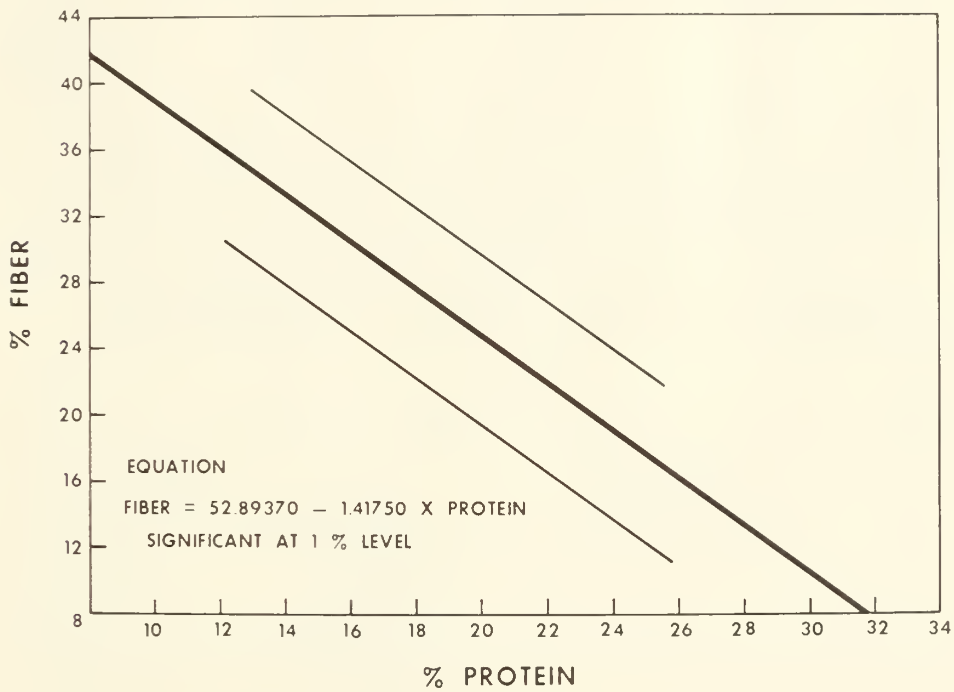

Figure 10.--Regression line of coarse fraction plus fine fraction for 1967 and 1968 operations at Darr, Nebr.

illustrated in Agricultural Economic Report No. 130 (14). The following table (14, p. 19) and excerpt (14, p. 6) from that report will serve to illustrate this. Parametric linear programming is a technique using electronic computers to determine at what price a particular feed ingredient of a specific composition will fit into a least cost ration and at what percent of that ration is in competition with other ingredients.

Comparisons of dehydrated alfalfa products at the xanthophyll point of substitution

Protein level of product	Intrinsic value of dehy	Dehy in ration	Cost of dehy per ton of ration	Total cost of ration
Percent	Dollars/ton	Percent	Dollars	Dollars/ton
13 1/	17.25	10.90	1.88	74.82
15	32.55	6.38	2.08	74.87
17	49.91	4.09	2.04	74.87
20	70.82	3.05	2.16	74.87
22	86.91	2.47	2.15	74.87
25	111.18	1.88	2.09	74.87
28	130.09	1.58	2.06	74.87

1/ 13-percent protein dehydrated alfalfa did not correspond to the same pattern as the other fractions. This was probably due to the influence of factors other than xanthophyll.

Source: U.S. Dept. Agr., Agr. Econ. Rpt. 130 (14, p. 19).

"Comparisons between value curves are perhaps of even greater interest than analysis of individual curves. Figure 2 [fig. 11] illustrates the value curves for 28, 17,

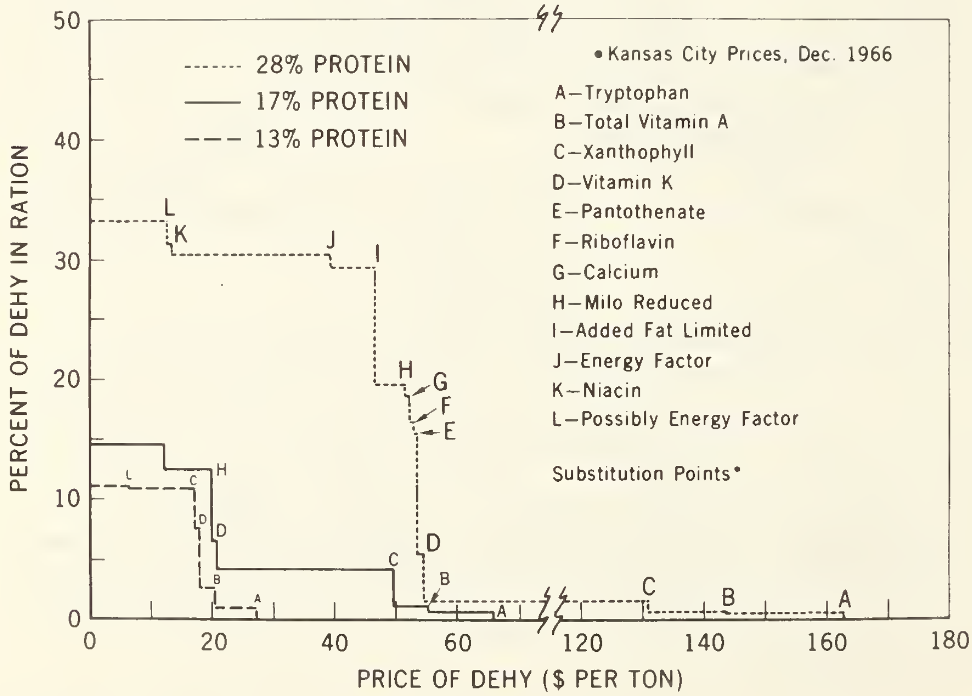

Figure 11.--Use of dehydrated alfalfa in broiler finisher ration related to quality and price (14).

and 13 percent protein dehydrated alfalfa meals in the broiler finisher ration. The curves are steplike because the functions are discontinuous. In comparing curves of different protein levels, the points of substitution are of greatest significance. As an example, point C on each of the curves is where xanthophyll in dehy substitutes for xanthophyll in corn gluten meal. Dehy of 28-percent protein content constitutes 1.5 percent of the ration at a value of $130 a ton; 20 percent dehy constitutes 3.1 percent of the ration at $71 a ton; 17 percent dehy is 4.1 percent of the ration at $50 a ton; and 13 percent dehy is 10.9 percent of the ration at $17 a ton."

REVIEW OF LITERATURE ON FEEDING VALUE OF COARSE FRACTION

D. A. Stiles and associates of Kansas State University in their Report of Progress 141 devoted a section to "Nutritive Value of Various Roughages Used in Dairy Calf Starters as Measured by Calf Growth."

Stiles and associates compared the five following rations;

Ration MV-1 - KSU calf starter with alfalfa hay (separate-not as pellet)
Ration MV-2 - KSU calf starter plus dehydrated alfalfa (complete pellet)
Ration MV-3 - KSU calf starter plus corn cobs (complete pellet)
Ration MV-4 - KSU calf starter plus ground alfalfa hay (complete pellet)
Ration MV-5 - KSU calf starter plus air separated corase fraction dehydrated alfalfa (complete pellet)

The calves were fed for 84 days and weighed weekly. Average daily gain (ADG) and feed consumed per pound of gain was:

	ADG	Lb. feed/lb. gain
MV-1	1.38	2.48
MV-2	1.19	2.30
MV-3	1.55	2.66
MV-4	1.44	2.26
MV-5	1.57	2.56

The ADG for the air-separated coarse fraction fed calves was highest of the five groups but the differences were not significant at ($P < 0.05$).

The air-separated coarse fraction, supplied from the Odessa, Nebr., phase of the fractionation project, on a 7-percent moisture basis showed an analysis of 17.8-percent protein and 31.2-percent fiber in our laboratory.

U. P. Garrigus of the Illinois University in unpublished data on lamb feeding experiments showed that average daily gains and gain per feed ratio of air-separated coarse fraction dehydrated alfalfa were better than those with standard (whole) dehydrated alfalfa. The differences were not significant ($P < 0.05$). Nitrogen balances were also in favor of the air-separated coarse fraction. The material sent to Dr. Garrigus analyzed, on a 93-percent total solids basis, 16.2 percent protein and 29.5 percent fiber. The fine fraction from the separation that produced that coarse fraction amounted to 35 to 40 percent of the whole by weight and analyzed about 22 percent protein and 21 percent fiber.

W. M. Beeson and associates at Purdue University reported at the Indiana Cattle Feeders Day, March 28, 1969, (page 35-39) that, "Alfalfa stem meal (15 percent protein) was equal to dehydrated alfalfa meal (17 percent protein) in Purdue 64 Dry high-urea supplement. This may indicate that the UPF factors for synthesis of protein from urea are contained in the coarse stem fraction of alfalfa as well as the whole plant." The "stems" referred to are air-separated coarse fraction dehydrated alfalfa.

	64A containing 17 percent regular dehy	64B containing 16 percent coarse fraction
Average daily gain, pounds	2.70	2.77
Feed/100# gain, pounds	670	650
Feed cost/lb. gain, cents	11.9	11.6

The air-separated coarse fraction, designated "stem meal" in this report was of the same lot used by the workers at Illinois University, 16.2 percent protein and 29.5 percent fiber on a 93 percent total solids basis. A much higher protein fraction had been removed from the whole alfalfa to make this coarse fraction.

J. R. Hibbs, T. J. Klopfenstein, and T. H. Deane of the University of Nebraska presented a paper before the Midwestern Section Meeting of the American Society of Animal Science in 1969, titled Quality of Alfalfa Stems. In the abstract of this paper are given data on a cattle growth trial and a lamb finishing trial. Twenty-eight steers averaging 253 kg. were individually fed one of the

four following rations for 140 days: First cutting stems, third cutting stems, chopped alfalfa hay, or a limited feed of an all concentrate ration. The "stems" referred to are air-separated coarse fraction dehy.

Digestibility of the rations was determined with lambs.

	First cutting stems	Third cutting stems	Alfalfa hay	All concentrate
Daily intake, kg./day	8.2	9.7	7.9	5.3
Average daily gain, percent	0.54	0.91	0.54	0.68
Dry matter digestibility, percent	50.9	58.1	60.2	91.0

The "stems" referred to are air-separated coarse fraction dehy. Twenty-seven ram lambs averaging 35.6 kg. were assigned to the one of the following treatments for 84 days: (1) 50 percent first cutting alfalfa stems and 50 percent ground shelled corn; (2) 50 percent third cutting alfalfa stems and 50 percent ground shelled corn; and (3) 50 percent chopped alfalfa hay and 50 percent ground shelled corn.

These results were obtained:

	Ration 1	Ration 2	Ration 3
Daily intake (kg./day)	1.8	1.8	1.7
Average daily gain (g./day)	243	263	222

With cattle and with lambs, the third cutting air-separated coarse fraction gave highest average daily gains.

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APPENDIX

TABLE 20.--Feed analysis of screen fractions

Analysis No. and screen sizes, mesh	Weight	Crude protein	Crude fiber	Fat	Ash	Grit
	Percent	Percent	Percent	Percent	Percent	Percent
No. 388-57:[1/]						
+ 14	--	--	--	--	--	--
- 14 + 20	0.2	--	--	--	--	--
- 20 + 30	0.4	13.2	37.8	2.3	7.0	--
- 30 + 40	2.2	10.6	41.3	2.0	6.1	0.23
- 40 + 60	16.6	10.8	39.0	2.0	6.6	--
- 60 + 80	18.1	14.2	32.2	2.3	8.0	--
- 80 + 100	8.0	18.1	25.2	3.1	8.6	--
-100 + 200	27.8	21.2	20.8	3.7	9.0	.35
-200	26.7	21.5	18.9	3.8	10.8	1.16
Weighted average	100.0	17.7	26.3	3.1	8.8	--
Original sample	--	17.7	26.7	3.6	9.5	.50
No. 388-45:[2/]						
+ 14	0.8	17.8	24.7	2.5	9.6	--
- 14 + 20	6.7	17.6	25.6	2.9	9.1	.59
- 20 + 30	7.9	16.4	27.8	2.6	8.9	--
- 30 + 40	12.4	15.4	30.0	2.6	8.3	--
- 40 + 60	22.5	15.4	29.1	2.6	8.2	--
- 60 + 80	13.8	17.5	25.3	2.9	8.9	--
- 80 + 100	4.8	19.0	24.0	3.2	9.1	--
-100 + 200	17.8	18.8	21.1	3.8	9.4	.82
-200	13.3	21.5	18.8	4.6	10.7	1.52
Weighted average	100.0	17.5	25.3	3.2	9.0	--
Original sample	--	17.8	27.0	3.4	10.5	.70
No. 388-47:[3/]						
+ 14	18.4	24.6	18.6	5.2	8.5	
- 14 + 20	22.9	24.0	19.2	5.4	8.4	.82
- 20 + 30	12.2	23.0	20.2	5.1	8.2	
- 30 + 40	10.8	22.5	21.1	5.2	8.1	
- 40 + 60	15.2	22.5	20.2	5.9	8.3	
- 60 + 80	8.4	24.5	17.9	6.6	8.4	
- 80 + 100	3.3	26.6	15.6	7.0	8.5	
-100 + 200	6.8	27.3	14.1	8.1	8.9	.70
-200	2.0	26.9	13.0	8.9	10.0	1.75
Weighted average	100.0	24.0	18.9	5.8	8.4	--
Original sample	--	24.0	19.3	6.2	8.8	.47

See footnote at end of table.

TABLE 20.--Feed analysis of screen fractions--continued

Analysis No. and screen sizes, mesh	Weight	Crude protein	Crude fiber	Fat	Ash	Grit
	Percent	Percent	Percent	Percent	Percent	Percent
No. 388-49:[4/]						
+ 14	0.7	18.5	23.3	3.6	9.5	--
- 14 + 20	5.7	18.4	24.0	3.4	9.4	0.70
- 20 + 30	7.4	17.0	25.5	3.7	9.5	--
- 30 + 40	10.1	15.5	28.2	3.2	8.8	--
- 40 + 60	21.6	15.4	27.6	3.4	8.9	--
- 60 + 80	14.7	15.8	23.8	4.0	9.4	--
- 80 + 100	8.2	19.7	19.8	4.5	9.1	--
-100 + 200	18.7	21.2	17.3	5.3	9.6	1.05
-200	12.9	21.8	13.9	6.5	11.5	2.45
Weighted average	100.0	18.1	22.4	4.3	9.5	
Original sample	--	18.3	24.0	4.7	9.9	.93
No. 388-51:[5/]						
+ 14	0.2					
- 14 + 20	7.9	17.0	25.3	3.1	9.9	0.93
- 20 + 30	10.9	16.1	27.4	2.9	9.3	--
- 30 + 40	12.8	14.8	29.6	2.8	9.2	--
- 40 + 60	23.0	15.0	28.3	2.8	9.1	--
- 60 + 80	14.3	17.4	24.8	3.2	10.2	--
- 80 + 100	7.6	19.2	20.5	4.1	9.9	--
-100 + 200	13.7	21.0	17.8	4.7	10.4	.82
-200	9.6	21.4	15.2	5.4	12.5	4.42
Weighted average	100.0	17.4	24.3	3.5	9.9	
Original sample	--	16.4	24.8	3.9	10.3	.70
No. 388-53:[6/]						
+ 14	1.1	15.4	28.7	2.8	9.8	--
- 14 + 20	7.4	15.0	30.2	2.3	9.8	1.86
- 20 + 30	8.7	14.2	32.3	2.3	9.1	--
- 30 + 40	15.8	13.5	35.7	2.2	8.5	--
- 40 + 60	26.6	14.3	33.3	2.1	8.7	--
- 60 + 80	14.3	16.1	29.2	2.4	10.4	--
- 80 + 100	4.6	17.3	26.3	2.5	11.6	--
-100 + 200	14.2	18.5	23.3	2.9	12.8	4.19
-200	7.3	18.6	22.3	2.8	14.6	6.86
Weighted average	100.0	15.5	30.2	2.4	10.2	--
Original sample	--	15.4	30.3	2.5	10.3	1.52

See footnotes at end of table.

TABLE 20.--Feed analysis of screen fractions--continued

Analysis No. and screen sizes, mesh	Weight	Crude protein	Crude fiber	Fat	Ash	Grit
	Percent	Percent	Percent	Percent	Percent	Percent
No. 388-55:7/						
+ 14	4.7	18.8	23.8	3.3	12.7	--
- 14 + 20	12.4	18.7	24.7	3.2	11.4	2.79
- 20 + 30	8.9	17.8	27.2	3.3	10.8	--
- 30 + 40	12.1	16.4	29.4	2.9	9.3	--
- 40 + 60	20.0	16.5	29.5	3.4	9.4	--
- 60 + 80	11.8	18.3	25.3	3.8	10.4	--
- 80 + 100	4.2	20.3	22.1	4.2	11.5	--
-100 + 200	15.1	21.9	19.3	4.7	12.0	2.79
-200	10.8	21.5	18.5	5.3	12.8	3.72
Weighted average	100.0	18.7	24.9	3.8	10.9	--
Original sample	--	18.5	24.6	4.1	11.4	2.73
No. 388-61:8/						
+ 14	7.34	16.4	20.7	4.9	10.2	--
- 14 + 20	11.36	16.7	21.0	4.9	10.2	0.35
- 20 + 30	7.34	16.6	20.8	4.6	9.8	--
- 30 + 40	7.04	16.1	21.0	4.5	9.7	--
- 40 + 60	18.49	15.6	21.7	4.1	9.6	--
- 60 + 80	18.69	15.5	23.2	4.2	9.9	--
- 80 + 100	10.75	17.0	22.0	4.7	10.0	--
-100 + 200	14.27	18.7	19.6	5.4	10.2	.35
-200	4.72	19.7	16.9	6.3	10.4	1.28
Weighted average	100.0	16.6	21.2	4.7	9.9	--
Original sample	--	16.5	21.5	4.7	10.2	--

1/ Original grind, 1,700 r.p.m. hammer mill, 74 3/4 inch diameter by 28 1/2 inch length, screen opening 8/64 inch (sifted through 24 mesh); regrind of 1/4 inch pellets, 3,600 r.p.m. hammer mill, 15 1/2 inch diameter by 28 1/2 inch length, screen opening 8/64 inch; 1 percent fat added; and ethoxyquin added.

2/ Original grind, 3,600 r.p.m. hammer mill, 24 inch diameter by 24 inch length, screen opening 5/64 inch; regrind of 1/4 inch pellets, 3,600 r.p.m. hammer mill, 24 inch diameter by 24 inch length, screen opening 8/64 inch; no fat added; and ethoxyquin added at regrinding mill.

3/ Original grind, 1,800 r.p.m. hammer mill, 40 inch diameter by 24 inch length, 10/64 inch screen opening; regrind of 1/4 inch pellets, 1,200 r.p.m. hammer mill, 28 inch diameter by 14 inch length, 10/64 inch screen opening; 1 percent fat added to pellets just ahead of regrinding mill; and ethoxyquin added in mixing chamber of pellet mill.

4/ Original grind, 3,600 r.p.m. hammer mill, 22 3/8 inch diameter by 26 inch length, 4/64 inch screen opening; regrind of 1/4 inch pellets, 3,600 r.p.m. hammer mill, 22 1/2 inch diameter by 26 inch length, 8/64 inch screen opening; fat added ahead of regrinding mill; and ethoxyquin added in mixing chamber of pellet mill.

5/ Original grind, 3,600 r.p.m. hammer mill, 27 inch diameter, 4/64 inch screen opening; regrind of 1/4 inch pellets, 1,750 r.p.m. hammer mill, 27 inch diameter, 4/64 inch screen opening; 1/2 percent fat added to pellets just before regrinding; and ethoxyquin added in mixing chamber of pellet mill.

6/ Original grind, 1,750 r.p.m. hammer mill, 49 inch diameter by 24 inch length, 8/64 inch screen opening; and regrind of 1/4 inch pellets, 3,600 r.p.m. hammer mill, 30 inch diameter by 22 inch length 8/64 inch screen opening.

7/ Original grind, 3,600 r.p.m. hammer mill, 24 inch diameter (alternate 1,750 r.p.m. 36 inch diameter), 3/64 inch screen opening; regrind of 1/4 inch pellets, 1,750 r.p.m. hammer mill, 24 inch diameter 8/64 inch screen opening; 1/2 percent fat added while regrinding; and ethoxyquin added in pellet mill mixing chamber.

8/ Original grind, 3,600 r.p.m. hammer mill, 24 inch diameter by 24 inch length, screen opening either 6/64 inch or 7/64 inch; regrind of 1/4 inch pellets, 3,600 r.p.m. hammer mill, 24 inch diameter by 20 inch length 12/64 inch screen opening; and no fat or antioxidant added.

TABLE 21.--Screen analysis

Proximate analysis and screen size, mesh		Sample 45	Sample 47	Sample 49	Sample 51	Sample 53	Sample 55	Sample 57	Sample 61
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
--	+ 14	0.8	18.4	0.7	0.2	1.1	4.7	0.0	7.3
- 14	+ 20	6.7	22.9	5.7	7.9	7.4	12.4	.2	11.4
- 20	+ 30	7.9	12.2	7.4	10.9	8.7	8.9	.4	7.3
- 30	+ 40	12.4	10.8	10.1	12.8	15.8	12.1	2.2	7.0
- 40	+ 60	22.5	15.2	21.6	23.0	26.6	20.0	16.6	18.5
- 60	+ 80	13.8	8.4	14.7	14.3	14.3	11.8	18.1	18.7
- 80	+100	4.8	3.3	8.2	7.6	4.6	4.2	8.0	10.8
-100	+200	17.8	6.8	--	13.7	14.2	15.1	27.8	14.3
-200		13.3	2.0	12.9	9.6	7.3	10.8	26.7	4.7
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Crude protein		17.8	24.0	18.3	16.4	15.4	18.5	17.7	16.5
Crude fiber		27.0	19.3	24.0	24.8	30.3	24.6	26.7	21.5
Fat		3.4	6.2	4.7	3.9	2.5	4.1	3.6	4.7
Ash		10.5	8.8	9.9	10.3	10.3	11.4	9.5	10.2

TABLE 22.--Analytical data of Lahontan alfalfa from California, 1963 crop (basis 93-percent total solids)

Cuttings	Starting material: Protein	Starting material: Fiber	Fine material: Weight	Fine material: Protein	Fine material: Fiber	Coarse material: Weight	Coarse material: Protein	Coarse material: Fiber	Fine fraction improvement: Points protein	Fine fraction improvement: Points fiber
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HAND SEPARATION										
First	18.4	26.3	34.03	31.6	10.4	65.97	11.6	34.4	13.2	15.9
Second	21.7	25.2	38.70	34.4	8.9	61.30	13.6	35.6	12.7	16.3
Third	19.8	25.8	39.80	32.3	9.3	60.20	11.4	36.7	12.5	16.5
Fourth	23.5	22.5	42.65	36.0	8.8	57.35	14.2	32.6	12.5	13.7
Fifth	24.2	25.8	48.88	35.6	14.9	51.12	13.4	36.3	11.4	10.9
Sixth	24.0	20.5	49.04	34.4	8.6	50.96	14.0	32.0	10.4	11.9
Seventh	24.1	22.9	47.02	32.0	11.9	52.98	17.1	32.6	7.9	11.0
Average	22.2	24.1	42.87	33.8	10.4	57.13	13.6	34.3	11.6	13.7
UNPROCESSED SEPARATION AT 12 MESH										
First	21.1	25.2	42.50	28.5	17.6	57.50	15.6	30.9	7.4	7.6
Second	20.5	27.3	34.30	29.3	16.0	65.70	15.9	33.2	8.8	11.3
Third	18.7	31.5	37.30	27.9	20.1	62.70	13.2	38.3	9.2	11.4
Fourth	21.6	23.8	44.56	29.0	14.2	55.44	15.7	31.4	7.4	9.6
Fifth	22.0	23.0	44.61	27.2	14.0	55.39	17.9	30.3	5.2	9.0
Sixth	23.7	22.7	46.35	31.3	13.2	53.65	17.2	30.9	7.6	9.5
Seventh	21.8	21.4	44.65	27.3	13.4	55.35	17.4	27.9	5.5	8.0
Average	21.4	25.0	42.04	28.6	15.5	57.96	16.1	31.9	7.2	9.5
PROCESSED SEPARATION AT 12 MESH										
First	21.6	24.4	52.40	28.2	17.2	47.60	14.4	32.3	6.6	7.2
Second	23.1	21.8	53.80	29.0	11.6	46.20	16.3	33.7	5.9	10.2
Third	19.4	28.0	47.41	27.2	17.5	52.59	12.4	37.5	7.8	10.5
Fourth	21.4	23.8	52.31	27.8	14.7	47.69	14.3	33.7	6.4	9.1
Fifth	22.3	18.9	58.46	26.0	11.0	41.54	17.1	30.0	3.7	7.9
Sixth	23.9	22.3	52.45	31.0	13.2	47.55	16.0	32.3	7.1	9.1
Seventh	21.9	22.8	52.81	26.6	14.1	47.19	16.2	32.6	4.9	8.7
Average	21.9	23.1	52.81	28.0	14.2	47.19	15.3	33.2	6.1	8.9
UNPROCESSED SEPARATION AT 8 MESH										
First	21.1	25.2	59.30	26.5	19.2	40.70	13.1	34.0	5.4	6.0
Second	20.5	27.3	54.70	26.9	18.6	45.30	12.8	37.8	6.4	8.7
Third	18.7	31.5	54.55	24.6	23.5	45.45	11.6	41.1	5.9	8.0
Fourth	21.6	23.8	63.62	26.2	17.2	36.38	13.5	35.3	4.6	6.6
Fifth	22.0	23.0	63.80	25.5	17.0	36.20	15.9	33.7	3.5	6.0
Sixth	23.7	22.7	63.58	29.3	15.3	36.42	14.0	35.5	5.6	7.4
Seventh	21.8	21.4	65.17	26.0	14.9	34.83	14.0	33.7	4.2	6.5
Average	21.4	25.0	60.67	26.4	17.9	29.33	13.5	35.9	5.0	7.1
PROCESSED SEPARATION AT 8 MESH										
First	21.6	24.4	68.00	26.2	19.3	32.00	12.0	35.3	4.6	5.1
Second	ig 23.1	21.8	71.60	27.5	14.5	28.40	12.2	40.4	4.4	7.3
Third	19.4	28.0	64.96	24.0	21.9	35.04	10.9	39.3	4.6	6.1
Fourth	21.4	23.8	69.61	25.4	17.8	30.39	12.2	37.5	4.0	6.0
Fifth	22.3	18.9	74.45	25.0	13.3	25.55	14.4	35.4	2.7	5.6

TABLE 22.--Analytical data of Lahontan alfalfa from California, 1963 crop (basis 93-percent total solids)--continued

Cuttings	Starting material		Fine material			Coarse material			Fine fraction improvement	
	Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber	Points protein	Points fiber
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
PROCESSED SEPARATION AT 8 MESH										
First	21.6	24.4	68.00	26.2	19.3	32.00	12.0	35.3	4.6	5.1
Second	23.1	21.8	71.60	27.5	14.5	28.40	12.2	40.4	4.4	7.3
Third	19.4	28.0	64.96	24.0	21.9	35.04	10.9	39.3	4.6	6.1
Fourth	21.4	23.8	69.61	25.4	17.8	30.39	12.2	37.5	4.0	6.0
Fifth	22.3	18.9	74.45	25.0	13.3	25.55	14.4	35.4	2.7	5.6
Sixth	23.9	22.3	66.84	29.2	15.1	33.16	13.1	36.8	5.3	7.2
Seventh	21.7	22.8	69.11	25.4	15.8	30.89	13.5	38.5	3.7	7.0
Average	21.9	23.1	69.22	26.1	16.8	30.78	12.6	37.6	4.2	6.3

TABLE 23.--Analytical data of Moapa alfalfa, California, 1963 crop (basis 93-percent total solids)

Cuttings	Starting material		Fine material			Coarse material			Fine fraction improvement	
	Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber	Points protein	Points fiber
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HAND SEPARATION										
First	22.0	26.2	36.80	35.3	10.0	63.20	14.2	35.6	13.3	16.2
Second	--	--	--	--	--	--	--	--	--	--
Third	19.7	25.6	44.98	30.9	10.9	55.02	10.6	37.6	11.2	14.7
Fourth	21.0	24.3	46.67	32.6	9.5	53.33	10.9	37.3	11.6	14.8
Fifth	19.8	26.0	43.42	31.9	10.3	56.58	10.6	38.0	12.1	15.7
Sixth	20.2	23.7	45.45	31.6	8.5	54.55	10.8	36.4	11.4	15.2
Average	20.6	25.2	43.46	32.5	9.8	56.54	11.4	37.0	11.9	15.4
UNPROCESSED SEPARATION AT 12 MESH										
First	20.4	28.5	35.50	29.3	18.0	64.50	15.5	34.3	8.9	16.5
Second	--	--	--	--	--	--	--	--	--	--
Third	19.4	27.2	43.91	27.4	16.3	56.09	13.1	35.8	8.0	10.9
Fourth	18.4	27.1	42.53	26.4	15.6	57.47	12.4	35.6	8.0	11.5
Fifth	20.6	25.2	40.31	28.4	14.9	59.69	15.3	32.1	7.8	10.3
Sixth	19.8	24.6	45.63	27.7	14.0	54.37	13.2	33.5	7.9	10.6
Average	19.7	26.5	41.58	27.8	15.8	58.42	13.9	34.2	8.1	10.7
PROCESSED SEPARATION AT 12 MESH										
First	21.8	27.2	45.10	29.7	17.2	54.90	15.3	35.4	7.9	10.0
Second	--	--	--	--	--	--	--	--	--	--
Third	19.1	26.6	49.87	26.4	16.3	50.13	11.9	36.9	7.3	10.3
Fourth	18.8	27.4	48.12	26.2	16.3	51.88	12.0	37.7	7.4	11.1
Fifth	20.8	23.7	47.84	28.3	14.2	52.16	13.9	32.5	7.5	9.5
Sixth	19.1	25.5	47.52	27.2	13.8	52.48	11.9	36.0	8.1	11.7
Average	19.9	26.1	47.69	27.6	15.5	52.31	13.0	35.7	7.7	10.3
UNPROCESSED SEPARATION AT 8 MESH										
First	20.4	28.5	54.80	26.5	20.8	45.20	13.0	37.9	6.1	7.7
Second	--	--	--	--	--	--	--	--	--	--
Third	19.4	27.2	62.00	24.6	19.8	38.00	10.9	39.4	5.2	7.4
Fourth	18.4	27.1	63.23	23.3	19.8	36.77	9.9	39.6	4.9	7.3
Fifth	20.6	25.2	59.17	26.1	17.4	40.83	12.5	36.5	5.5	7.8
Sixth	19.8	24.6	61.66	25.4	16.5	38.34	10.8	37.7	5.6	8.1
Average	19.7	26.5	60.17	25.2	18.8	39.83	11.4	38.2	5.5	7.7
PROCESSED SEPARATION AT 8 MESH										
First	21.8	27.2	64.00	27.1	20.3	36.00	12.4	39.3	5.3	6.9
Second	--	--	--	--	--	--	--	--	--	--
Third	19.1	26.6	67.83	23.4	20.3	32.17	10.1	39.9	4.3	6.3
Fourth	18.8	27.4	67.45	23.2	20.7	32.55	9.7	41.3	4.4	6.7
Fifth	20.8	23.7	65.45	25.9	16.6	34.55	11.1	37.2	5.1	7.1
Sixth	19.1	25.5	62.91	24.5	17.2	37.09	10.1	39.6	5.4	8.3
Average	19.9	26.1	65.53	24.8	19.0	34.47	10.7	39.4	4.9	7.1

TABLE 24.--Analytical data of Buffalo alfalfa, from Kansas 1963 crop (basis 93-percent total solids)

Cuttings	Starting material		Fine material			Coarse material			Fine fraction improvement	
	Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber	Points protein	Points fiber
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HAND SEPARATION										
First	24.4	17.5	48.73	33.4	9.4	51.27	15.9	25.2	9.0	8.1
Second	20.6	26.1	47.02	30.1	12.3	52.98	12.1	38.3	9.5	13.8
Third	18.9	28.2	45.16	28.0	12.4	54.84	11.3	41.1	9.1	15.8
Fourth	17.3	28.2	45.95	27.0	11.3	54.05	9.0	42.5	9.7	16.9
Fifth	22.0	20.9	50.16	31.6	9.5	49.84	12.3	32.4	9.6	11.4
Average	20.6	24.2	47.40	30.0	11.0	52.60	12.1	35.9	9.4	13.2
UNPROCESSED SEPARATION AT 12 MESH										
First	23.5	13.4	27.80	22.7	11.4	72.20	23.9	14.6	(0.8)[1]	2.0
Second	20.1	23.1	45.30	26.2	14.9	54.70	14.9	29.9	6.1	8.2
Third	19.7	22.4	28.31	25.2	14.9	71.69	17.5	25.4	5.5	7.5
Fourth	17.9	22.9	17.27	22.8	12.6	82.73	16.9	25.1	4.9	10.3
Fifth	22.5	18.5	52.58	26.8	12.3	47.42	17.8	25.3	4.3	6.2
Average	20.7	20.1	34.25	24.7	13.2	65.75	18.2	24.1	4.0	6.9
PROCESSED SEPARATION AT 12 MESH										
First	23.1	13.0	45.00	22.7	9.8	55.00	23.4	15.6	(0.4)[1]	3.2
Second	20.4	24.4	55.11	26.3	15.9	44.89	13.3	34.8	5.9	8.5
Third	18.8	23.7	42.31	24.6	13.9	57.69	14.5	30.8	5.8	9.8
Fourth	18.0	22.2	32.59	22.8	12.3	67.41	15.7	27.0	4.8	9.9
Fifth	22.1	19.5	57.41	26.9	12.7	42.59	15.7	28.6	4.8	6.8
Average	20.5	20.1	46.48	24.7	12.9	53.52	16.5	27.4	4.2	7.2
UNPROCESSED SEPARATION AT 8 MESH										
First	23.5	13.4	50.60	25.0	10.7	49.40	22.0	16.2	1.5	2.7
Second	20.1	23.1	67.20	24.5	17.0	32.80	10.9	35.7	4.4	6.1
Third	19.7	22.4	52.45	24.2	15.7	47.55	14.7	29.8	4.5	6.7
Fourth	17.9	22.9	42.84	22.3	14.6	57.16	14.6	29.1	4.4	8.3
Fifth	22.5	18.5	73.58	25.8	13.4	26.42	13.2	32.5	3.3	5.1
Average	20.7	20.1	57.33	24.4	14.3	42.67	15.1	28.7	3.7	5.8
PROCESSED SEPARATION AT 8 MESH										
First	23.1	13.0	68.70	24.2	10.6	31.30	20.5	18.3	1.1	2.4
Second	20.4	24.4	74.42	24.1	18.8	25.58	9.8	40.8	3.7	5.6
Third	18.8	23.7	66.23	22.8	16.4	33.77	10.9	37.9	4.0	7.3
Fourth	18.0	22.2	60.82	21.8	15.1	39.18	12.3	33.3	3.8	7.1
Fifth	22.1	19.5	74.60	25.6	14.3	25.40	11.8	34.8	3.5	5.2
Average	20.5	20.6	68.95	23.7	15.0	31.05	13.1	33.0	3.2	5.6

TABLE 25.--Analytical data of Ranger alfalfa, from Nebraska, 1963 crop (basis 97-percent total solids)

Cuttings	Starting material		Fine material			Coarse material			Fine fraction improvement	
	Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber	Points protein	Points fiber
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
				HAND SEPARATION						
First	23.2	23.9	47.75	32.0	12.8	52.25	15.2	34.1	8.8	11.1
Second	14.0	32.4	34.50	22.3	12.3	65.50	9.6	43.0	8.3	20.1
Third	17.0	34.5	35.75	30.4	12.8	64.25	9.6	46.5	13.4	21.7
Fourth	19.2	27.6	40.04	30.7	10.8	59.96	11.4	38.9	11.5	16.8
Fifth	22.9	18.8	52.08	31.5	9.1	47.92	13.4	29.4	8.6	9.7
Average	19.3	27.4	42.02	29.4	11.5	57.98	11.8	38.4	10.1	15.9
				UNPROCESSED SEPARATION AT 12 MESH						
First	21.6	24.0	33.35	27.1	17.1	66.65	18.9	27.5	5.5	6.9
Second	16.0	32.5	24.70	24.6	18.0	75.30	13.2	37.3	8.6	14.5
Third	16.0	29.3	19.42	23.3	16.1	80.58	14.3	32.4	7.3	13.2
Fourth	16.9	29.3	18.50	25.5	16.6	81.50	15.0	32.2	8.6	12.7
Fifth	25.7	16.4	32.03	30.4	11.9	67.97	23.1	18.5	4.7	4.5
Average	19.3	26.3	25.60	26.2	15.9	74.40	17.0	29.6	6.9	10.4
				PROCESSED SEPARATION AT 12 MESH						
First	21.8	24.1	41.59	27.3	17.1	58.41	17.9	29.1	5.5	7.0
Second	15.6	32.1	31.78	24.1	18.1	68.22	11.7	38.6	8.5	14.0
Third	16.1	28.7	29.35	23.0	15.8	70.65	13.3	34.0	6.9	12.9
Fourth	17.7	28.3	27.49	25.9	16.4	72.51	14.5	32.8	8.2	11.9
Fifth	26.4	16.6	47.33	30.0	12.9	52.67	23.1	19.8	3.6	3.7
Average	19.5	25.9	35.51	26.0	16.1	64.49	16.1	30.9	6.5	9.8
				UNPROCESSED SEPARATION AT 8 MESH						
First	21.6	24.0	55.94	25.6	18.9	44.06	16.6	30.5	4.0	5.1
Second	16.0	32.5	46.80	21.4	23.5	53.20	11.3	40.5	5.4	9.0
Third	16.0	29.3	38.14	21.7	19.2	61.86	12.5	35.5	5.7	10.1
Fourth	16.9	29.3	37.50	23.0	19.7	62.50	13.3	35.1	6.1	9.6
Fifth	25.7	16.4	55.74	29.3	12.7	44.26	21.0	21.1	3.6	3.7
Average	19.3	26.3	46.82	24.2	18.8	53.18	14.9	32.5	4.9	7.5
				PROCESSED SEPARATION AT 8 MESH						
First	21.8	24.1	63.10	25.7	19.1	36.90	15.1	32.7	3.9	5.0
Second	15.6	32.1	53.89	20.6	23.8	46.11	9.8	41.8	5.0	8.3
Third	16.1	28.7	50.12	21.0	19.6	49.88	11.3	37.8	4.9	9.1
Fourth	17.7	28.3	46.11	23.5	19.4	53.89	12.6	35.9	5.8	8.9
Fifth	26.4	16.6	69.76	29.1	13.5	30.24	20.1	23.5	2.7	3.1
Average	19.5	25.9	56.60	24.0	19.1	43.40	13.8	34.3	4.5	6.8

TABLE 26.--Summary analytical data of Lahontan, Moapa, Buffalo, and Ranger varieties, all cuttings (basis 93-percent total solids)

Variety and cuttings	Starting material		Fine material			Coarse material			Fine fraction improvement	
	Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber	Points protein	Points fiber
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HAND SEPARATED										
Lahontan, 7	22.2	24.1	42.87	33.8	10.4	57.13	13.6	34.3	11.6	13.7
Moapa, 5	20.6	25.2	43.46	32.5	9.8	56.54	11.4	37.0	11.9	15.4
Buffalo, 5	20.6	24.2	47.40	30.0	11.0	52.60	12.1	35.9	9.4	13.2
Ranger, 5	19.3	27.4	42.02	29.4	11.5	57.98	11.8	38.4	10.1	15.9
Average	20.7	25.2	43.98	31.4	10.7	56.06	12.2	36.4	10.8	14.6
UNPROCESSED SEPARATION AT 12 MESH										
Lahontan, 7	21.4	25.0	42.04	28.6	15.5	57.96	16.1	31.9	7.2	9.5
Moapa, 5	19.7	26.5	41.58	27.8	15.8	58.42	13.9	34.7	8.1	10.7
Buffalo, 5	20.7	20.1	34.25	24.7	13.2	65.75	18.2	24.1	4.0	6.9
Ranger, 5	19.3	26.3	25.60	26.2	15.9	74.40	17.0	29.6	6.9	10.4
Average	20.3	24.5	35.87	26.8	15.1	64.13	16.3	29.9	6.5	9.4
PROCESSED SEPARATION AT 12 MESH										
Lahontan, 7	21.9	23.1	52.81	28.0	14.2	47.19	15.3	33.2	6.1	8.9
Moapa, 5	19.9	26.1	47.69	27.6	15.5	52.31	13.0	35.7	7.7	10.3
Buffalo, 5	20.5	20.1	46.48	24.7	12.9	53.52	16.5	27.4	4.2	7.2
Ranger, 5	19.5	25.9	35.51	26.0	16.1	64.49	16.1	30.9	6.5	9.8
Average	20.5	23.9	45.62	26.6	14.7	54.38	15.2	31.8	6.1	9.2
UNPROCESSED SEPARATION AT 8 MESH										
Lahontan, 7	21.4	25.0	60.67	26.4	17.9	39.33	13.5	35.9	5.0	7.1
Moapa, 5	19.7	26.5	60.17	25.2	18.8	39.83	11.4	38.2	5.5	7.7
Buffalo, 5	20.7	20.1	57.33	24.4	14.3	42.67	15.1	28.7	3.7	5.8
Ranger, 5	19.3	26.3	46.82	24.2	18.8	53.18	14.9	32.5	4.9	7.5
Average	20.3	24.5	56.25	25.1	17.5	43.75	13.8	33.8	4.8	7.0
PROCESSED SEPARATION AT 8 MESH										
Lahontan, 7	21.9	23.1	69.22	26.1	16.8	30.78	12.6	37.6	4.2	6.3
Moapa, 5	19.9	26.1	65.53	24.8	19.0	34.47	10.7	39.4	4.9	7.1
Buffalo, 5	20.5	20.6	68.95	23.7	15.0	31.05	13.1	33.0	3.2	5.6
Ranger, 5	19.5	25.9	56.60	24.0	19.1	43.40	13.8	34.3	4.5	6.8
Average	20.5	23.9	65.08	24.6	17.5	34.92	12.5	38.1	4.1	6.4

Table 27.--Analytical data, product and component distribution by plots, Ranger alfalfa, Cozad, Nebr. 1965 (Dry sifting at 7-percent moisture basis)

Plot No.	Cuttings	Starting material		Fine material			Coarse material			Fine fraction improvement	
		Protein	Fiber	Weight	Protein	Fiber	Weight	Protein	Fiber	Points protein	Points fiber
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Dry sifted dehy											
1	2	22.4	25.4	57.3	27.9	16.7	42.7	15.0	37.1	5.5	8.7
2	2	19.4	29.5	49.1	25.9	17.7	50.9	13.1	41.0	6.5	11.8
3	2	18.6	30.6	48.6	25.8	18.0	51.4	11.8	42.5	7.2	12.6
4	2	17.9	31.3	48.4	25.6	17.5	51.6	10.6	44.2	7.7	13.8
All plots	2	19.6	29.2	50.9	26.3	17.4	49.1	12.5	41.4	6.7	11.8
Field samples Hand separated											
1	2	23.4	25.0	38.2	36.5	9.5	61.8	15.4	34.6	13.1	15.5
2	2	20.3	29.3	34.6	34.1	9.6	65.4	13.0	39.7	13.8	19.7
3	2	19.4	31.4	32.6	33.7	9.9	67.4	12.4	41.8	14.3	21.5
4	2	17.9	30.9	32.5	32.5	10.1	67.5	10.9	40.9	14.6	20.8
All plots	2	20.2	29.1	34.5	34.3	10.0	65.5	12.9	39.3	14.1	19.0
Dry sifted dehy											
1	3	19.5	26.4	56.4	25.0	16.4	43.6	12.4	39.4	5.5	10.0
2	3	17.9	26.9	50.3	24.1	18.3	49.7	11.7	35.6	6.2	8.6
3	3	17.6	29.8	50.7	24.6	17.3	49.3	10.4	42.7	7.0	12.5
4	3	16.7	31.6	46.8	23.6	18.6	53.2	10.6	43.1	6.9	13.0
All plots	3	17.9	28.7	51.1	24.4	17.6	48.9	11.2	40.2	6.5	11.1
Field samples Hand separated											
1	3	19.8	26.4	40.6	31.0	10.0	59.4	12.1	37.7	11.2	16.4
2	3	18.8	29.4	40.0	31.2	12.8	60.0	10.6	40.5	12.4	16.6
3	3	18.6	28.8	43.3	30.1	11.5	56.7	9.8	41.9	11.5	17.3
4	3	17.0	30.0	38.7	27.9	11.6	61.3	10.2	41.5	10.9	18.4
All plots	3	18.6	28.6	40.6	30.1	11.5	59.4	10.7	40.4	11.5	17.1
Dry sifted dehy											
1	both	21.0	25.9	56.9	26.5	16.5	43.1	13.7	38.3	5.5	9.1
2	both	18.7	28.4	49.7	25.0	18.0	50.3	12.4	38.3	6.3	10.2
3	both	18.1	30.2	49.7	25.2	17.6	50.3	11.1	42.6	7.1	12.6
4	both	17.3	31.5	47.6	24.6	18.0	52.4	10.6	43.6	7.3	13.4
All plots	both	18.8	28.9	51.0	25.3	17.5	49.0	11.9	40.8	6.6	11.4
Field samples Hand separated											
1	both	21.6	25.7	39.9	33.6	9.7	60.1	13.8	36.1	12.0	16.0
2	both	19.6	29.4	37.3	32.6	11.3	62.7	11.8	40.1	13.0	18.1
3	both	19.0	30.1	38.0	31.6	10.8	62.0	11.2	41.8	12.6	19.3
4	both	17.5	30.4	35.6	30.0	10.9	64.4	10.5	41.2	12.5	19.5
All plots	both	19.4	28.9	37.6	32.0	10.7	62.4	11.8	39.8	12.6	18.2

Machinery

The Sweco Separator we used in the Western Regional Research Laboratory, Albany, Calif., is a Model 51853333-18 inch. The screen area is 14 inches in diameter. It is manufactured by Southwestern Engineering Company in Los Angles. This firm builds similar equipment of much greater diameter for commercial application.

The scalper used in Cozad, Nebr., in 1965 was built in Fresno, Calif., by Commercial Manufacturing and Supply Co. It is a simple mechanical screening device with a 3/4 hp. motor. The active screen area is 22.5 by 90.5 inches, or 2,036 square inches. We dressed it with punched steel screen with 6/64-inch round openings.

The air separator used at Odessa and Darr, Nebr., was manufactured by Scientific Separators, Inc., of Denver, Colo.

Figure 12 shows the general conformation of an air separator.

The zigzag column of our unit is 90 inches tall, 50 inches wide, and space in the column is 4 inches between straight sections of the zigzag. The material is fed into a hopper at the top by a slotted housing screw conveyor of 8-inch diameter. The slot in the conveyor housing does not run straight, end to end of the conveyor but curves downward toward the outer end to afford even distribution across its 50-inch length. At the bottom of the hopper is a rotary valve to feed into the column about one-fourth of the distance from top to bottom of the zigzag column. The transition is an odd-shaped piece 4 by 50 inches at the top of the column to tangential opening on the cyclone separator. The bottom outlet of this cyclone is equipped with another rotary valve to discharge the fine material. The coarse material falls free from the bottom of the column. The blower draws air from the top of the cyclone and discharges to the atmosphere. We calibrated the valve on the blower outlet by using a Hastings-Raydist velocity meter in the center of the column just above the bottom outlet.

We had the use of a California Pellet Mill Co. 50 hp. Century mill equipped with a die having 3/4 inch square openings. We also had the use of a CPM flat bed pellet mill making a wafer-type pellet either ca. 1 inch by 1/2 inch or ca. 1 1/4 inch by 3/4 inch. These two mills were used to pellet the coarse fraction. For the fine fraction, a CPM 50 hp. mill with 1/4-inch die was used.

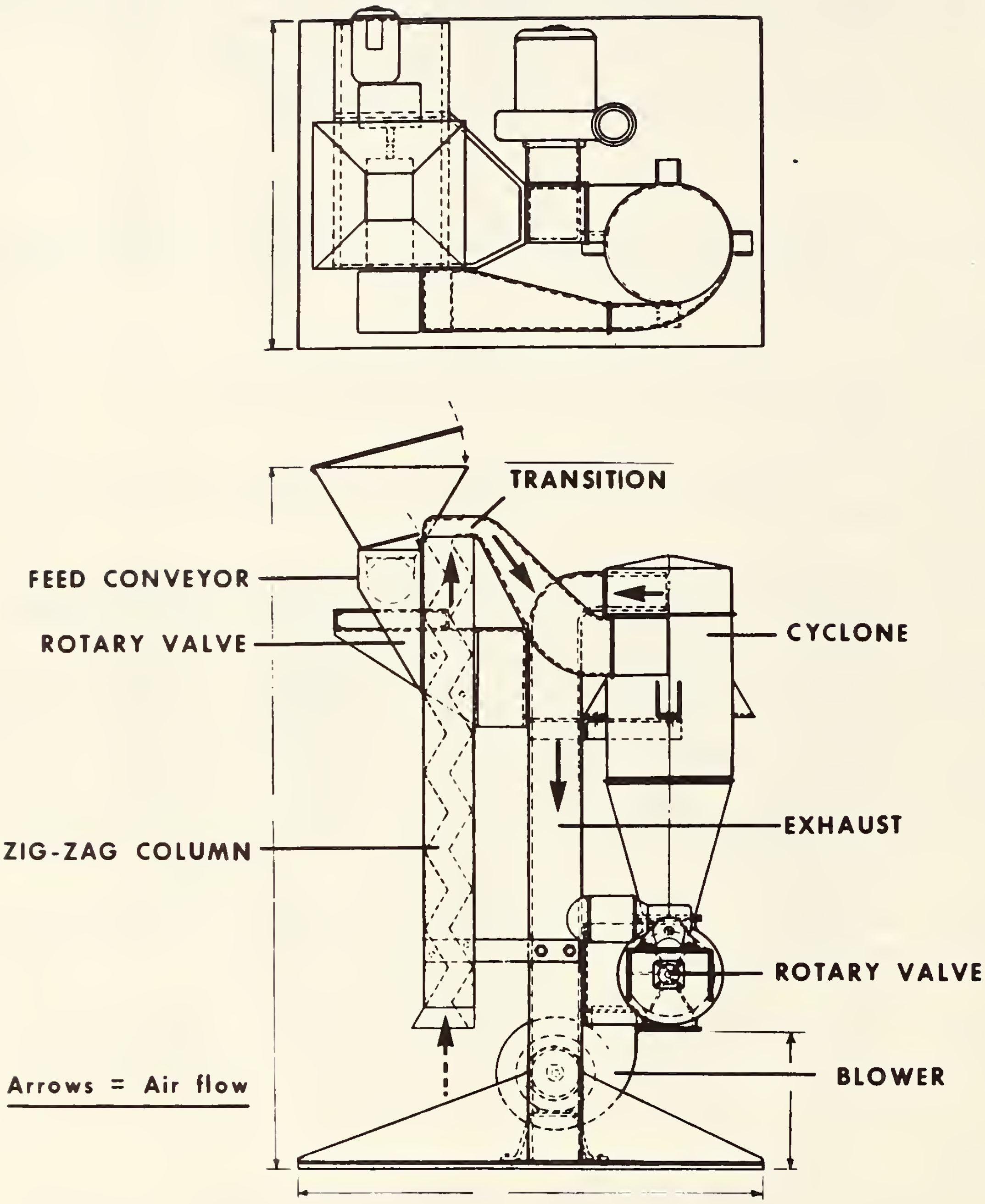

Figure 12.--Diagrammatic sketch of air separator.

A horizontal cooler was used for the coarse material pellets and a vertical cooler for the 1/4-inch fine material pellets. Both were manufactured by the California Pellet Mill Co.

An alfalfa dehydration unit was assembled on a 40- by 8-foot trailer bed. The mobile plant consisted of a pilot-sized dehydrator (Heil Model No. SD 45-12) rated to handle 1,000 pounds of water per hour from alfalfa chops, standard vertical type 10 hp. Reitz disintegrator, a 15 hp. Jacobson hammer mill, a Hagopian-type horizontal oscillating screen, and zigzag air classifier (fig. 13).

The specifications for the dehydrator are as follows:

<u>Dimension</u>: 6 feet - 2 inches wide x 11 feet - 6 inches high x 20 feet - 0 inch long.

<u>Furnace</u>: Side-fired single, venturi-type main gas burner with a pneumatic controlled throttling valve, a Maxon safety switch solenoid valve. Maximum gas consumption 2,000 cubic feet of 1,000 B.t.u. per cubic feet natural gas at 15 p.s.i.g. at the burner.
(In 1969 the venturi-type gas burner was replaced with a Maxon wide range burner (Model WR-4), a micro-ratio air-gas throttling valve (M-4 x 2-1/2 - P), and a positive pressure primary air blower (Model L-8000-8).)

<u>Feeder</u>: Overall dimensions 7 feet 2 inches long x 5 feet 10 inches wide x 5 feet 6 inches high, capacity 45 cubic feet. Driven by 1-1/2 hp. motor that actuated the rake back, feed rolls, and discharge screw conveyor. The feed rate was maximally adjusted through a Speedomax controlling the travel of the metal flight bars that provide a continuous live bottom.

<u>Conveyor</u>: Drag-type metal slats riveted to single strand chain carried in sheet metal housing with built-in air seals. Unit driven through a roller chain and sprockets from power shaft on feeder.

<u>Drum</u>: Three pass 4-1/2 feet by 12 feet with compound showering flights. Variable speed, positive chain drive (0 to 15 r.p.m.). Unit supported by cast iron rollers, carried on ball bearing, self alining pillow blocks.

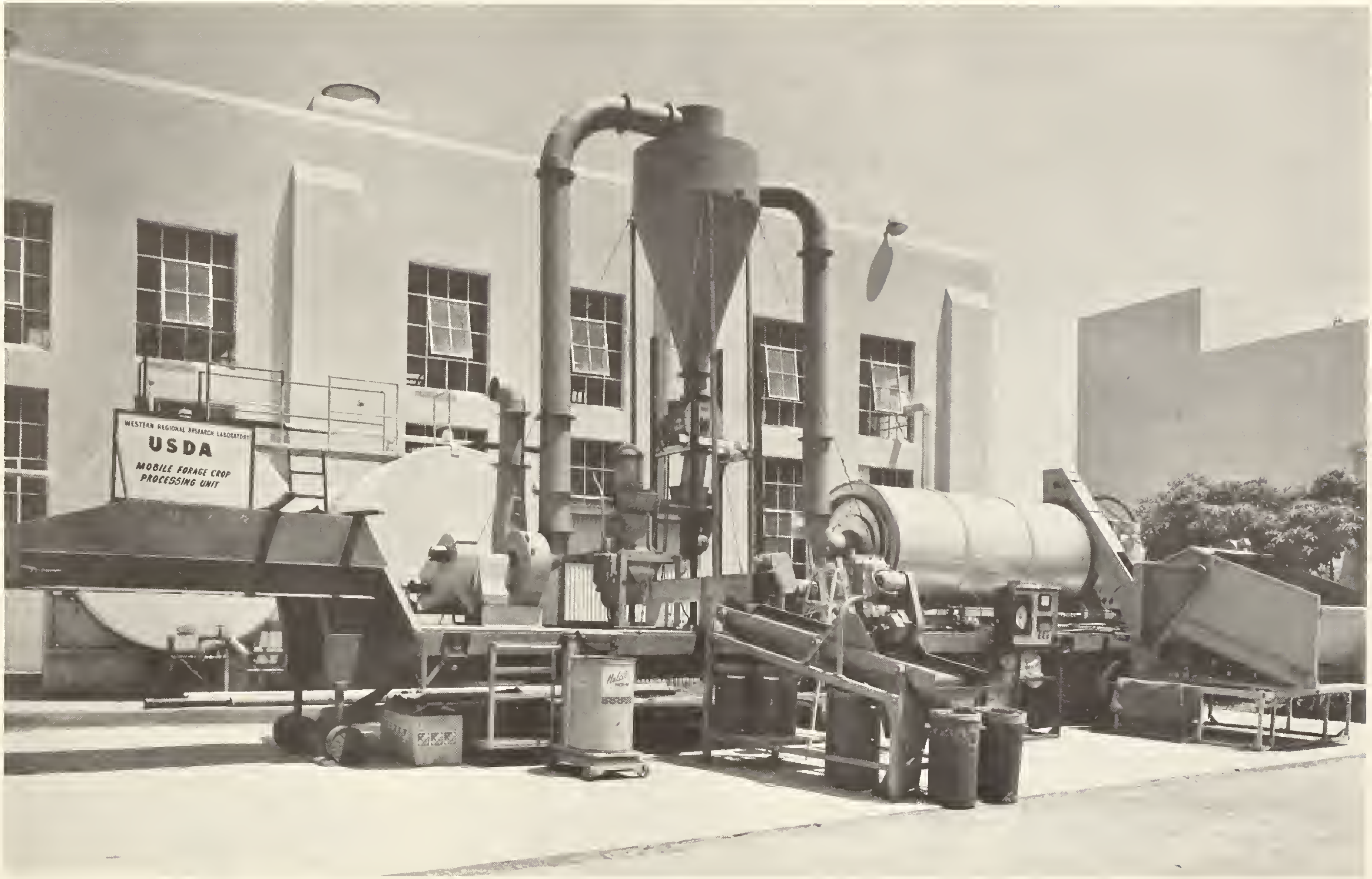

Figure 13.--Mobile dehydrator and appurtances.

Controls: Pneumatic Recorder Controller Taylor Model B124, dual pen 0° to 500° F. used to control the exit drum air temperature. The combustion chamber temperature was monitored by a chromel-alumel thermo couple via an electrical pneumatic transducer, Taylor 700T Model 2. Flame ignition was controlled by a Barber Coleman "Flam-otrol," Model 1470.

Fan: The original fan on the dehydrator was modified to provide variable speeds capable of operating from 1,500 to 2,400 r.p.m. In 1966 the cyclone was operated under negative pressure. The alfalfa chops from the feeder were conveyed to the drum and discharged under positive pressure to the cyclone. The dehy then could be, at the discretion of the operator, fed to the Reitz disintegrator to effect a leaf stem cleavage or to the hammer mill. If the product went to the Reitz mill, the leaf and stem separation was made by the oscillating horizontal Hagopian screen separator or the zigzag air classifier.

GPO 980-819

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